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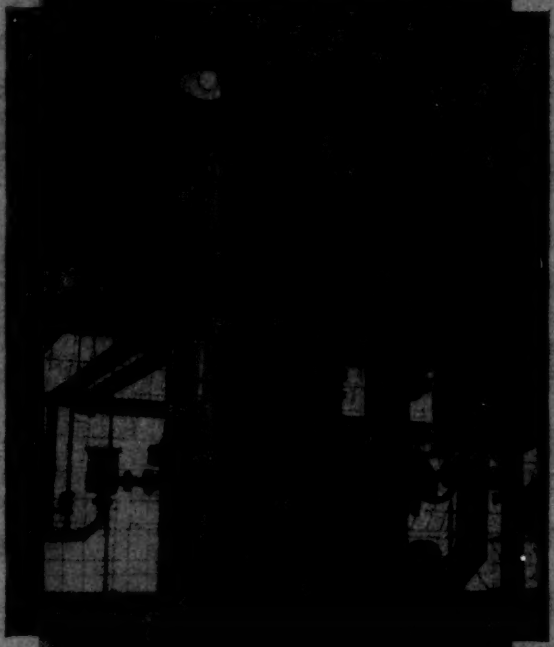
WELDED Industrial Piping



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JOURNAL

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Better Welding Through Non-Destructive Tests

(Reprinted from Sept. 21, 1929, issue Electrical World)

Some of the uncertainties in regard to the strength of welded joints and the craftsmanship of the welder may be rendered less perturbing to the skeptical engineer-designer if the test equipment reported upon at the recent Cleveland meeting of the American Welding Society meets present expectations. The ordinary stethoscope of the physician — provided, however, with a gum-rubber tip to exclude extraneous sounds and give contact on an irregular surface, as well as to minimize damping of oscillations—may be used for the investigation of welded joint strengths. If the point to be tested be struck with a small hammer, a sound is heard which is critical and shows the character of the material at the point struck. Preliminary tests establish the characteristic sounds for each structure.

The Sperry rail-testing device has proved its value for weld inspections offering a rapid, ink record of the soundness of the weld. This device consists essentially of apparatus, moved along the material to be tested, for passing an electric current between two main contact brushes between which are three auxiliary brushes. Current passing from the first to the second passes through a transformer coil, while that from the second to the third passes through a similar coil wound in the opposite direction on the same core. A homogeneous material will be evidenced by an equal current in each coil, each neutralizing the magnetic effects of the other, while lack of uniformity will produce a disturbance in the core which is picked up by the secondary of the transformer and amplified by radio tubes to operate recording or indicating apparatus.

A comparatively inexpensive, reliable method for determining the strength of welded joints is as inevitable as it is necessary. Such a test must be readily applicable to the many variations in size, shape and thickness of the materials involved, and the equipment must be capable of easy transportation for quick tests on the job, relatively inaccessible though it may be. When such a device is perfected, welding will be beyond all serious rivals for metallic joining, for it will be demonstrably certain where riveting, bolting or crimping is of necessity guesswork in no small degree.

Welding and Cutting Nomenclature, Definitions and Symbols

A bulletin of welding and cutting nomenclature definitions and symbols is published as a supplement to this issue. This bulletin has been under preparation by the American Welding Society for the past three years and because of its fundamental and comprehensive nature, it represents one of the most valuable undertakings of the Society to date. This is especially true at the present time on account of the tremendous increase in the use of welding and cutting, and because it has become increasingly difficult to obtain a clear conception of the ideas expressed by various authors due to the diversified terminology which has already crept into use through a lack of standardization.

The text, exclusive of the index, consists of 43 pages, with numerous cuts. It is divided into four sections. Section I covers nomenclature; Section II, definitions of general welding terms, processes, forms of joints, forms of welds, and equipment and supplies; Section III, abbreviations, and Section IV, symbols.

Under Nomenclature in Section I, the names of the principal welding processes are given in full, and there is a schematic diagram of the principal welding processes illustrating

graphically their inter-relation. The definitions in Section II and abbreviations in Section III are profusely illustrated so that there can be no misunderstanding of what is meant. Finally the symbols in Section IV are for use in connection with the resistance and fusion welding processes.

A copy of these standards should be in the hands of every engineer, designer, contractor, welding foreman, and indeed anyone using any of the welding processes, as they will be invaluable aid in their work.

The committee was made up of authorities on the various welding processes, and a representative from the United States Bureau of Standards. Its make up is as follows:

James W. Owens, Newport News Shipbuilding & Dry Dock Co., chairman.

A. M. Candy, Westinghouse Elec. & Mfg. Co.

J. J. Crowe, Air Reduction Sales Co.

J. H. Deppeler, Metal & Thermit Corp.

W. B. Miller, Union Carbide and Carbon Research Laboratories.

H. H. Moss, Linde Air Products Co.

W. L. Warner, General Electric Co.

H. L. Whittemore, U. S. Bureau of Standards.

H. A. Woofter, Swift Electric Welder Co.

In the Introduction to the Standards, the committee expresses its appreciation for the help rendered it by F. T. Llewellyn, the president of the Society, and by F. M. Farmer, chairman of its Committee on Standard Tests for Welds, also to the Newport News Shipbuilding & Dry Dock Co. for its technical and clerical assistance in the preparation of the cuts and manuscript.

Copies of the bulletin can be obtained from the headquarters of the American Welding Society, 33 West Thirty-ninth Street, New York, N. Y. Its price is 50 cents.

New Members Secured in "Member for Member Membership Campaign" October 15th to November 15th, 1929, and Proposers

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F. W. Wilson	F. T. Llewellyn
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G. M. Heinle	C. M. Rusk
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L. P. Caproni	J. D. Tierney
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A. C. Badger	No proposer

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F. E. Freeman	G. W. Swan
C. M. Drahl	No proposer
Wm. Meyer	No proposer

SECTION ACTIVITIES

Chicago

The Chicago Section met at Greer College of Automotive Engineering, Thursday, Nov. 7, at which the scope of structural welding in the Chicago District was discussed. Over one hundred were in attendance to listen to this discussion and to watch the demonstration of arc welding which followed.

Mr. J. J. Wallace, of the Joliet Engineering Co., Joliet, Ill., talked on

the economic aspects of welding as it affects the structural contractor. He illustrated his talk with several slides showing some of the work that his company has done in this field. He was followed by Mr. A. L. Wilson of the Mississippi Valley Structural Steel Company, of Melrose Park, Ill., who told of the experience of his company with welding in the fabrication of steel structures. He discussed at length the adaptability of welding to various types of structures, the designs used in work of this kind, the organization of shop and field details and various methods of inspecting and testing finished work.

Following these two talks, Mr. George O. Rohder, of the C. H. Hollup Corp., Chicago, gave a practical demonstration of operating difficulties experienced in arc welding and methods to be used in eliminating them.

Los Angeles

On November 12, the Los Angeles Section held a very interesting meeting. The subject of the meeting was "The Largest All Welded Truss Ever Made in the World." This truss was made for the Forest Lawn Mausoleum at Glendale. Mr. Charles Kyson spoke for the Forest Lawn Memorial Association. Mr. P. M. Matchmor talked for the Barton Brown Engineering Corp. on the inspection. Mr. David Hall, Westinghouse Electric & Mfg. Co., spoke on "Welding and Its Application to Structural Steel Work." Mr. A. W. Lewis, Pacific Iron & Steel Co., gave a short talk on the welding of structural steel from the fabricator's standpoint. The Westinghouse Electric & Mfg. Co. furnished musical entertainment for the evening.

Philadelphia

"Pipe Welding as Applied to Industrial and Building Operations" was the subject of the meeting of the Philadelphia Section held on November 18. The paper was presented by Mr. John N. Zink, president, The Heat & Power Corporation. A lively discussion followed the presentation of the paper.

San Francisco

The October meeting of this Section was held on the 18th. Mr. Henry D. Dewell, consulting engineer, spoke on "The New California Uniform Building Code as It Applies to Structural Steel Welding." Mr. Dewell advised the Society what the code has to say regarding welding of buildings. The code will be published in the near future.

Western New York

The regular monthly meeting of the Western New York Section was held at the Hotel Statler, Buffalo, on Oct. 22. The speaker was Mr. I. T. Hook, testing engineer of the American Brass Company, of Waterbury, Conn. His subject was "Welding Copper, Brass, Bronze and Other High Copper Alloys."

Mr. Hook proved to a large audience that he was thoroughly conversant with the present history as well as the ancient history of copper and its alloys. He illustrated many interesting points with lantern slide pictures.

New York

One of the most successful meetings of the New York Section was held as a joint session with the American Society of Civil Engineers on Nov. 20. Illustrated reviews of the subject of Structural Steel Welding were presented by Prof. F. P. McKibben, consulting engineer, General Electric Company; Mr. A. G. Leake, president, Leake & Nelson Co., Inc., and Mr. H. M. Priest, assistant engineer, American Bridge Company. These talks were supplemented by a motion picture film on a Gas Welded Building. A spirited discussion followed on many phases of the subject, including cleaning of parts to be welded, relative costs, inspection and proper methods of design. About 650 people were present.

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Discussion of Technical Papers

Presented at Fall Meeting of the American Welding Society

TUESDAY MORNING—Sept. 10, 1929

A. E. GAYNOR, Presiding.

Discussion of paper "The Effect on Design of the Use of Welding in the Manufacture of Electric Machinery,"* by Henry G. Reist, General Electric Co.

Mr. H. Ullmer, Linde Air Products Co.: Mr. Reist has portrayed most interestingly the modifications of design which were evolved by the application of welding to the construction of electric machinery. Assuming that these structures are economically sound, it will only be a question of time before the unique advantages of this form of fabrication will be generally adopted by machinery manufacturers, resulting in a material expansion of the use of welding and cutting.

We of the American Welding Society collectively and as individuals, can do a great deal to foster the development and early adoption of this method of fabrication by making available to those interested and in a position to accept them, the results of our intensive research and experience in our respective processes, provided the trend of machine design and manufacture is in the direction of welded steel shapes.

Mr. Reist has stated that most of the large machines described are special, requiring new patterns if made of castings, thus adding to the development expense. Also that the saving of time is an important reason for the use of rolled steel welded construction.

In this connection I should like to ask to what extent welded steel construction has been applied by his company in the manufacture of all sizes of electric machinery units. Do you not find practical limitations in substituting welded shapes for castings?

Mr. Reist: We have no definite limit as to where we use rolled steel and where we use castings, but whenever we have a machine we think of welded construction first, and nearly always make it that way. Sometimes the reason for using castings is because the customer wants a duplicate of an old machine.

We don't keep patterns very long. About two years after the last use they are destroyed, as the storage space is too valuable and they get out of repair, so it is only very exceptional that we make a cast steel frame in these days.

Whether it is desirable to make a piece by casting or by welding largely depends on their relative costs of material and of labor. The material used in making welded parts is cheaper than cast metal. If the

*Paper published in September, 1929, issue *Journal* of the A. W. S.

welding cost can be kept low and the piece is heavy, it will probably be profitable to make it from structural material.

Mr. Ullmer: In your opinion, is welded construction destined to entirely supplant castings in this field, or is it probable that the ultimate structure will be composite combining both castings and welded units?

Mr. Reist: I think it will always be composite, to a certain extent. If we can make a part more cheaply by using a casting, we will make it that way, but I think we can do a great deal more with welding rolled material than we have done so far.

It seems to be pretty well appreciated in the electric manufacturing business now that there are decided advantages in the welded construction over the use of casting. The welding of large parts of electrical machinery was started at Schenectady but was soon taken up by the other leading manufacturers, both in this country and France, England and Germany.

A British company has recently published a report of their progress with welding which showed very extensive use there.

Mr. Ullmer: Undoubtedly this type of construction has curtailed the activity of the foundry. To what extent has the foundry organization participated in the new construction, if any?

Mr. Reist: Some foundries have been curtailed in their work, but they are gradually finding other things to make and are perhaps manufacturing a little more economically than before. They have been spurred to greater economy. Maybe on the whole it is a good thing for the foundry.

I might say the same thing has happened to the machine shop. As I explained, we can weld parts quite accurately to dimension, so the amount of machining has been materially reduced. Certain portions we can make sufficiently accurate to size with no machining.

President Llewellyn: I hesitate to discuss a paper on machinery, for it is not my line, but there is a thought that arises out of other fields that may perhaps be applicable to the question of machine design.

I noticed that Mr. Reist's very interesting paper several times referred to things that had been done for the sake of appearance. Appearance is an important matter, whether it be in a machine or a structure, a bridge or a building—it is a feature that is being considered more and more, and discoveries are being made in other fields which perhaps may bear on machine design, discoveries of principle.

I don't need to remind you that certain forms standardized in machine design were not used primarily as adornment. The flare and the curved fillet, in a cast iron part, were not originally put there for the sake of appearance. The flare was put there because you had to have a flare to draw the pattern out of the sand. The fillet was put there because a sharp reentrant corner in a casting is an invitation to cracks.

Now, I am very much in sympathy with any attempt to make machines esthetic. I am absolutely opposed to any attempt to do so by copying what was originally one of the handicaps of another material. I think

the proper procedure is to consider function first, and then to make the parts as esthetic as is consistent with function.

Let us draw a parallel from another field, the field of structural design. Thirty-five or forty years ago the first skyscraper was put up with skeleton construction, and some architects very naturally imitated the prevailing masonry construction. They deliberately constructed ornament. You may ornament construction; you should never construct ornament.

In Chicago they went to the other extreme, and put up skyscrapers without any ornament at all, with the result that they have some mammoth buildings there—I am speaking of buildings put up thirty years ago, not recent buildings—that are nothing but hideous boxes.

More recently it has been realized that the tall building involves other essentials, namely, the need for light and air. As a result, our city ordinances require what is commonly called setback, whereby, after you have passed a certain height, your building wall must recede by a given proportion. The result has been marvelous. Not only does it give light, air, and higher rentals to the more desirable spaces up high, but it has greatly improved the appearance of the building, and that not by the construction of ornament, but by the beauty of line, the beauty of proportion, the beauty of shadow.

I am not qualified to make any suggestion in detail with regard to machine design, but I do suspect that a study of essentials, and then the rounding off of those essentials along neat lines, will probably bring results that are very much better than any attempt to slavishly copy what was a requirement in another material.

Just one suggestion, and I make it very tentatively. In the second picture that Mr. Reist showed, there were a couple of large I-beams, thirty feet long, as I recall it, in which the ends had been curved, for the sake of appearance, in a quadrant. If my recollection of school statics is correct, the stresses in a beam acting as those beams do, are closely represented by the curve of a parabola, and I throw out the suggestion, has anybody tried curving off the ends of those beams along the line of a parabola?

If my suggestion is a poor one, put it in the waste paper basket, but I do emphasize the desirability of attempting to secure beauty by the study of fundamental conditions rather than trying to imitate some other material.

Mr. Reist: The speaker referred to shaping those parts according to a parabola. The particular picture that he referred to had that shape. I would like to have that thrown on the screen again. (The slide was thrown on)

Our ordinary practice has been to round the upper corner of the end of I-beams to a radius of half the depth of the beam. But in this particular beam, the depth is so great that it seemed desirable to make the end parabolic.

President Llewellyn: It was the preceding picture that I had in mind.

Mr. T. T. Copeland, Carnegie Steel Co.: On page 147 of your paper, you show a cast stator frame for a horizontal shaft generator; you also showed on the screen a picture of a welded construction of stator frame of a horizontal shaft generator.

(a) Do you know the relative cost between the cast design, and the fabricated and welded design?

(b) Do you experience any difficulty in holding in alignment in diameter and circumference of the fabricated and welding design?

(c) In the welding of fabricated machinery, especially complicated design, have you found it necessary to anneal after welding to relieve the strains set up?

Mr. Reist: It is very difficult for me to give a comparison of costs because the art isn't well enough organized to give that exactly, but I might say, in many cases the costs were so near the same that the only saving was due to the saving of cost of the pattern, but we expect a difference of 20 to 30 per cent in the two types of construction.

It is our practice to anneal wherever we use welding on rotating parts, and not on stationary parts. On stationary structures, it is usually possible to arrange for so wide a margin of safety that if there are defects in the welding it is not serious. On rotating parts, it seems desirable to anneal the parts and remove all welding strains.

Mr. J. C. Lincoln, Lincoln Electric Co., Cleveland: It happens that the Lincoln Electric Co. have been using this process of welding in the construction of machinery for quite a while. The development of the process in our factory has been very gradual. I think it was about 1912 or 1913 that the first welded structure was produced. That was a compensator can which was probably 15 inches wide, say, 10 inches thick, and 20 inches high, and you can see that a structure of that sort would be very difficult to cast, and was. We had to pay a very high price per pound for those castings, and we had to reject about half that we obtained. The can that we substituted for that was made out of sixteen-gauge sheet steel, weighed probably not much over 10 per cent of the weight of the corresponding iron castings, and the costs were something like one-fifth for the welded can that we had to pay for the cast cans. We have sent out something over a hundred thousand of those cans, all over the country, and, so far as I know, we have had no complaint on any of them up to the present time.

That was a rather auspicious introduction to the use of this method to the construction of machinery for us, and we have extended its use until at the present time our machinery is built, if you please, around the process of electric welding. Instead of having cast rings on our stators, we take a piece of angle iron, heat it, roll it, weld the ends together, and use those two angles as the side member of the stator on all sized stators, from the smallest to the largest.

If the cost of these parts is desired in this discussion, I can send in some cuts of the costs of a number of these parts, and the costs in the particular case we have in mind are determined in this way: The old cast structure would cost so much; labor of machining the cast struc-

ture would cost so much. In the new welded structure, the cost of the welding would be so much, which would be added to the cost of the material. No overhead is added for either the old or the new construction. Therefore, in comparing costs, that fact should be kept in mind.

These costs show that as a general thing the welded construction is very much less expensive than the old cast construction. That is true, in a general way. So far as we or our customers are concerned, the emphasis ought to be laid, not on costs, but on the quality of the resulting machine.

When we built our stators, for instance, out of our cast end rings, we had them riveted together, and we would put them under a hydraulic press and put all the pressure we could on them before riveting, but the pressure is limited by the strength of the cast end ring. I think our pressures were something like ten tons before riveting with our old cast structures. Since we have adopted our steel end ring, welded, that same pressure is put up to about seventy tons before riveting. As a consequence, our present stators are very much more rigid than our old stators could have been, and as a result of that, our present stators are better structures, make a better stator for a motor, than our old structure.

Now, in reference to the difference in appearance: I think that there is no question that the use of this welding method necessarily is going to make machines of a different appearance than were produced by the old method of casting. I think that we will have to accept that as something that we cannot get away from.

We feel at our place just as Mr. Reist has indicated, that after we are used to it, the new structure is as pleasing to the eye as the old. In many cases it is even more pleasing. What we are used to is ordinarily more pleasing to the eye than what we are not used to.

In that connection I am reminded of a trip I took some years ago to Guatemala, one of the most progressive of the Central American states. Guatemala is only about 75 miles from the Pacific Coast. We went from the Carribean Sea, and went 150 miles to Guatemala City. One of the attractions there is a group of statues of ladies put in the park, and the extraordinary thing about them is that the ladies are dressed in the fashions of 1894, with bustles and balloon sleeves and long skirts, and if you can imagine any more laughable statues than those are to our present eyes, I can't guess where you will find them. The difference between the appearance of those statues now and the appearance of those statues when they were made, isn't in the statues; it is in our eyes; it is what we are accustomed to.

I think the criterion which ought to be used in deciding whether the appearance is proper or not is simply this: Is the design the one which will produce the best results in the best way? If the design is the one which produces the desired results in the best way, its appearance will be satisfactory, after we are used to it.

Our President, Mr. Llewellyn, has pointed out, when that criterion is used in the construction of tall buildings, a beautiful building such as

the Woolworth Building, is the result. He pointed out that some of these structures that Mr. Reist has shown could have been modified so that he could have got a parabolic beam and the appearance might have been more pleasing than it is, and at the same time we would certainly save some metal, so it strikes me that the criterion which should be used in this introduction of the welding tool into the construction of machinery is not, "Does it look like the old thing which it replaces?" That ought not to be used. The criterion which should be used is, "Does it do the work in the most satisfactory and economical manner?"

Mr. James W. Owens, Newport News Shipbuilding and Dry Dock Co.: Mr. Reist has presented an excellent paper, and the extensive application of welding to machinery design shown by him will assist machine manufacturers to eliminate castings in the manufacture of their product.

As the question of cost largely influences the extensive application of welding, it seems desirable to bring the following points to your attention:

(a) Design has probably more influence on cost reduction than any other factor, and the primary aim of the designer should be not only to save material but to eliminate every possible operation and reduce the amount of welding to a minimum.

(b) In the past, it has frequently happened, that in order to secure the consent of the customer to use welding, it was necessary to promise joints of 100 per cent strength, with the result that the cost of the job has been increased, due to the unnecessary amount of welding and the frequent necessity of straightening the job on its completion due to warping. This state of affairs, however, is gradually changing, for the customer is beginning to realize that the strength of welded joints can be calculated as accurately as riveted joints, and that it is, therefore, not necessary to make every joint a 100 per cent strength joint.

(c) It is necessary to consider the extensive use of jigs. I have known cases where by a proper application of jigs, construction problems would have been simplified and warping eliminated.

(d) The cost of welding is sometimes increased by inspectors requiring the peening of the finished weld. If the *last layer* is peened, the weld will probably be inferior to an unpeened weld if subjected to bending stresses. This being the case, it becomes necessary for users of welding not only to educate the customer to accept unpeened welds but to produce welds having faces which are relatively smooth, free from gobs of weld metal and craters, also to use weld gages so as to insure a uniformity of weld contour.

(e) In some cases it will be found more economical to use both steel castings and plate construction in the structure. The designer should not hesitate to do this when necessary, for a steel casting is sometimes cheaper than a part built up of plates and shapes welded together. Because of this, I consider that there will always be a need of foundries.

(f) As a welded product can, in general, be made lighter than a cast or riveted product, it will sometimes be found that the cost of shipment

will be materially less. Unfortunately, this is often overlooked in an analysis of cost reduction by means of welding.

(g) Although the indirect savings obtained by welding are sometimes difficult to determine, nevertheless they have an important bearing on cost reduction and should not be ignored. For example, it is frequently found impossible to properly maintain a carefully prepared work schedule in a machine shop, because defective castings prevent deliveries to the shop on schedule time and rejections are sometimes necessary even on the last machining operation. Conditions such as this not only disorganize the work schedules but, when excessive, will even break down the morale of the shop.

(h) In the application of welding, it has been found that although overall costs may be less than the former method of manufacture, yet the cost in one department might be higher, particularly if this department has never previously undertaken a similar welded job. Should such a department be operating on a budget based on the former method of manufacture, and the efficiency of the department is judged on its ability to keep within the budget, it is likely that the management will obtain unfavorable reports of welding costs from the head of the department. It is therefore necessary to carefully watch for conditions such as this so that the true state of affairs can be presented to the management.

Although I have only touched on a few of the items influencing cost reduction by means of welding, it is obvious that a true estimate of cost reduction can only be obtained by a broad, impartial, and sympathetic attitude of the management toward welding. This being the case, it is as necessary to educate the management as it is to train the design and shop departments to properly use the process. In general, it will be found that welding has made the most remarkable strides in those plants wherein the management is thoroughly convinced of the advantages of the process, are men of vision and daring, and their whole organization knows that they will not be frustrated in their determination to apply modern methods in the manufacture of their product. Two outstanding examples are Henry Ford and Edward Budd. The plants of both of these men are today large welding laboratories and welding has made cost reductions possible which could not have been secured in any other way. Insofar as the Westinghouse and General Electric companies are concerned, welding hardly made any progress until very definite orders were issued a few years ago by their managements to use the process wherever possible. The results of this policy in the General Electric Co. have been described to you this morning by Mr. Reist.

Mr. Herbert A. Woofter, Swift Electric Co., Detroit: In reading articles on welded members for several years, practically all of them I have noted have been for dead or centrifugal loads. I should like to ask of Mr. Reist, or anyone else, if anything has been done toward making frames for hydraulic presses, bulldozers and other structures, that must have a constant load of enormous intensities, two or three times a minute, year in and year out, and especially where the line of pres-

sure must come above the axial line of the frame itself. If such a frame has ever been designed and used, how was the deflection taken care of?

In many welding jobs nowadays the overall length of the finished work must be held to within a very few thousandths of an inch. The deflection in a structural steel frame, when a load of two to three hundred thousand pounds is used, is many times more than that in any type of ordinary mill-rolled section that you can get, so I should like to be enlightened along that line.

Now, with regard to appearance: It has been my experience and perhaps yours, that the finer-looking and finer-appearing a machine is, the easier it is to market it, and other things being equal, you and I, and I believe everyone else, will buy the finer-looking machine in preference to the crude-looking one. The same thing applies to a horse, if you are going to buy one. Two horses may be able to pull exactly the same load, but you will buy the finer-looking one; or an automobile, or a pair of shoes, or what not.

So it seems to me appearance must always be taken into consideration —whether it is a house, a machine or what not. If anyone can enlighten me on any of the above, I should like to hear from them.

Mr. A. M. Candy, Westinghouse Electric & Mfg. Co.: Mr. Chairman and Gentlemen: I hadn't intended to say anything but the urge to get back of the microphone is so great that I feel I must speak.

The gentlemen who have spoken before had a tendency to go back into history, so to speak, and point out how long welding had been done. I am not in a position to say how long our company has been using it. Twenty years ago when I went to East Pittsburgh, I saw the flash of something in the factory and I thought lightning had struck it, but when I got into the factory I found they were arc welding. That was on a relatively small scale compared with what is being done today, but it shows how long the arc welding art has been in use.

The question of cost has come up strongly today along with appearance, and it seems to me that the question of cost for the average manufacturer who is considering adopting welding for his product instead of using castings or other shapes, is something he must work out for himself to a very large degree. I might stand up here and talk to you for half an hour, telling you how we have installed a $250,000 rolling mill and welding plant to turn out our welded machinery, but that wasn't the beginning of it.

What we did was to get our designers to pick out some of the most simple parts that we manufacture and see wherein those designs could be changed to provide a minimum of welding work.

Now, my suggestion is that any of you who are interested in going into this sort of work, do the same thing. It is all right to get the other fellow's costs, but in the long run that doesn't mean much to you in your plant. His plant and his facilities are different. What you must do is start on a small scale, build up an organization for doing the welding, and build it up on an economical basis. It means that you must buy some welding machines, and see that you have some welding operators

trained and have some of your men go to some of the plants where the work is being done, get some of the fundamental ideas and go back and use their brains, and I am sure you will get results.

I would like to ask a question about the annealing temperature. There seems to be considerable disagreement among metallurgists as to the temperature at which to anneal rotating parts, to relieve locked up stresses due to the welding. I would like to have Mr. Reist advise us from their experience what temperature would be best. Some recommend 1000 deg. Fahr., and some go up to 1600 deg. Fahr., and so there is quite a divergence of opinion.

Mr. Reist: Mr. Chairman, I have very little to add to this. We have no experience with the use of welding in machinery with stresses such as are found in presses, etc., but I do not think there would be much difficulty in constructing machinery of that type because we can build an I-beam form of construction rather easier than it can be made out of castings. On some of the bridges that I called attention to, we have very great loads. As it is important that they have only a very small deflection, they are made much stiffer than the requirements for highway or railroad bridges. These bridges are loaded with half a million to a million and a half pounds with a deflection in the neighborhood of one-sixteenth of an inch.

I am very much gratified at the interest which is shown in appearance of machines. I think it is very important. It is a subject that I have been very much interested in for a good many years. I quite agree with one of the speakers, if you make it right mechanically, it usually looks well. Perhaps it may be difficult to decide when it is right; perhaps that is why some machines don't look well. But we don't want any extraneous ornament on the machine; just design it well mechanically and probably we will have a good-looking piece of machinery.

I can't help but suggest a little history in connection with these modern tall buildings, as our architect friend pointed out, where we step back with increasing height. I wonder if we all appreciate that that is a strictly American form of construction. It was invented by the Southwestern Indians who built their houses, and have for centuries, with step back construction just about like our modern tall buildings.

Mr. Charles S. Dresher, Link-Belt: He omitted to answer the question about annealing temperature.

Mr. Reist: We anneal some steel now at about 600 deg. C.

Mr. Dresher: Have you difficulty in keeping articles in alignment?

Mr. Reist: No, very little. They are usually braced by a brace which holds them in shape and we have very little difficulty in changing form afterward.

Discussion of paper "Cutting and Welding of Steel Parts to Replace Castings" * by W. J. Buchanan, Cooper Bessemer Co.

Mr. H. Ullmer, Linde Air Products Co.: Mr. Buchanan's paper clear-

*Paper published in the September, 1929, issue Journal of the A. W. S.

ly outlined the progress over the past year in the application of mechanical cutting to the manufacture of Diesel engine parts, and there is every reason to believe that his prediction for the further expansion of gas cutting as applied to that particular industry will be realized.

The development of machines capable of automatically reproducing parts in any quantity to close tolerances is responsible for the increasing popularity of gas cutting in many industries. Heretofore, these industries have not found it possible to adopt oxy-acetylene cutting to regular production operations.

As evidence of the broad application of mechanical cutting in industry during the past year, production shape cutting has been adopted by some of our most important manufacturers of electric generating equipment, Diesel engines of stationary and marine types, steam shovels and heavy rod machinery, pumps, heavy forgings, granite saws, sheet metal working machinery, in ship yards, etc.

It is significant to note that one of the largest distributors in the country of steel plates, structural shapes, etc., has equipped its warehouses in three important industrial centers with shape cutting machines and have employed a special corps of sales representatives to solicit orders for steel shapes cut to the customer's pattern. This organization has experienced no difficulty whatever in keeping the shape cutting machines operating steadily since they were installed and the success in this particular case may be interpreted as indicative of possible radical changes in merchandising and purchasing certain classes of steel plates and billets.

To revert to the subject under discussion, Mr. Buchanan's paper, there is only one portion of this that I will take the liberty to comment on, which refers to his statement that "no harm is done to the metal by this cutting, as some people suppose, and no difficulty is found in making machine cuts in the material after it has been under the cutting flame."

Much could be said on this subject of a highly technical nature, but for the purpose of qualifying Mr. Buchanan's statement, I believe it will suffice to state that no harmful effect whatsoever has been encountered in oxy-acetylene cutting steel plates, bars and shapes having a carbon content not over 0.25 per cent. It is our practice, however, to recommend that plates, billets and forgings of higher carbon content than 0.25 per cent be properly preheated before gas cutting and, in some special cases, normalized following the cutting.

There are several essential reasons for preheating. A physical change occurs in the face of the cut when steel is cut cold, although this is not pronounced in low carbon steels. This change is a hardening effect along the face of the cut penetrating 1/16 in. to ⅛ in. into the metal and is caused by the rapid conduction of heat from the face of the cut into the large body of cold metal. The effect is similar to hardening by quenching.

This sudden cooling also sets up expansion and contraction stresses in the cut face of the metal as it cools, due to the fact that during the

cutting operation the face of the cut is heated to a temperature high enough to cause expansion to take place in the surface metal. Then, as the cold body of steel does not expand a corresponding amount, it is obvious that this narrow band of metal will become shortened or upset, and when the heated metal is cooling this expanded area must contract, causing it to stretch and adjust itself parallel to the face of the cut. If the ductility of the metal is not sufficient to permit this adjustment or stretch, the surface will check.

While the hardening which takes place on the face of steel cut cold is not enough to prevent machining, except with the higher carbon steels, such as tool steel, the ductility in steels with more than 0.25 per cent carbon is not great enough to permit the expansion and contraction of cutting cold without introducing the possibility of surface checking. Preheating eliminates both the hardening and the contraction stresses to a negligible point.

Preheating to 1100 deg. Fahr., in addition to decreasing both the time of cutting and the consumption of gases, prevents both the physical changes due to hardening and the expansion and contraction stresses, because in cutting preheated metal, the expansion in the entire body is approximately equal to the expansion on the face of the cut, the upsetting or shortening of the cut face is prevented, thereby removing the possibility of checking and also the rapid cooling, which causes hardening.

Mr. A. M. Candy, Westinghouse Elec. & Mfg. Co.: I would like to ask Mr. Buchanan if he has had any experience in welding the parts cut by the oxy-acetylene torch and if any cleaning is necessary?

Mr. W. F. Buchanan: On all of our cutting we are very particular that all the slag is cleaned off, otherwise no cleaning is done on these until the job is done.

In this paper a part is mentioned eighteen inch channel iron, fifteen feet long, on which considerable welding is done. We have had no trouble whatever in welding these parts, or any others, that have been cut on the shape cutting machine.

In answer to Mr. Ullmer, I wish to state that in all of our cutting, anything that is over two inches in thickness is preheated before we do any cutting on it.

Mr. Lincoln, Lincoln Electric Co.: This is a subject I know nothing about, but it does interest me to inquire why it is that material over two inches should be preheated before cutting. Evidently the reason is to decrease the chance for hard spots or hair cracks on the surface of the material, but why does preheating do any good? I can see why annealing after would, but why does preheating?

Mr. Buchanan: By preheating you save time and you also save gas, and you might as well preheat before and then anneal afterward.

Mr. Lincoln: Are these pieces that you preheat annealed later?

Mr. Buchanan: We heat the parts first, that saves time and also gas and then we anneal them afterward.

After the cutting is done it does not take much heating to bring the parts up to the annealing point.

Mr. Lincoln: They are annealed to prevent any hair cracks on the hard surface?

Mr. Buchanan: Yes.

TUESDAY AFTERNOON

September 10, 1929

H. L. WHITTEMORE, Presiding.

Discussion paper on "The Welding of Copper and Copper Alloys" * by I. T. Hook, American Brass Co.

Mr. Rudolf Krause, Westinghouse Elec. & Mfg. Co.: I would like to ask Mr. Hook for information about the sketch, showing how to increase the strength of the metal, adjacent to the weld (See Figure 4a on page 117 of the Sept. copy). Do you have any commercial method of making that particular shape, or is it just for laboratory work?

Mr. Hook: No, sir. The way in which all of these specimens were made was by actually beveling the ends for the V groove, on a milling machine or shaper.

Mr. Kraus: Still another question in regard to the statements about the qualifications for the welder (See page 126, Sept. copy, paragraph "Men").

I do not like the statement that the engineer should leave it to the welder to choose the method, the rod, and the flux, if any. As the engineer knows the composition of the material he selected for a particular purpose, he can more readily specify what the welder should use.

Mr. Hook: I think it would be necessary in a process which had been worked out in detail to write down a specification which would indicate to the welder what type of rod he should use, what method of welding, and what flux, and, of course, it goes without saying, what base metal.

I was thinking, when I stated that the welder should have great versatility, that it would be desirable to find such a welder. They are very difficult to find, but nevertheless, if we did have a welder of that type, we would have a man who is more valuable on work as varied as work in a non-ferrous shop. There are so many of these alloys, and the nature of them is so complex, that it is a difficult matter to specify procedure for every type of welding that you are liable to encounter.

Mr. Chas. H. Jennings, Westinghouse Elec. & Mfg. Co.: In looking over some of the tables that are given in Mr. Hook's paper, I noticed that in nearly every case he obtained the greatest ultimate strength from the smallest test specimen. Several typical examples of this can

*Paper published in the September, 1929, issue Journal of the A. W. S.

be found in his results. In Series 2, the results of two specimens welded with a manganese bronze rod show the ultimate strength of one specimen 0.215 in. thick to be 14,100 lb./sq. in. and the ultimate strength of the other specimen 0.072 in. thick to be 22,770 lb./sq. in.

In the Series 6 tests, this same tendency is shown for welds made on silicon-manganese-copper. A test specimen with a critical section of 0.158 sq. in. developed an ultimate strength of 36,880 lb./sq. in., while a specimen of 0.071 sq. in. critical section developed an ultimate strength of 48,460 lb./sq. in.

I feel that Mr. Hook has introduced another variable by using different sizes of test specimens, and that great care must be taken in the interpretation of results obtained from different size specimens.

Mr. Hook: I would say there are three reasons for the obtaining of a higher strength on a thinner metal. In the first place, the thinner the sheet that we start with, ordinarily the greater work it has had upon it, and therefore the greater strength of the sheet metal. In other words, if we take dead soft metal in real thin sheet, it is apt to run a little higher in tensile strength than dead soft metal in quite a thick section. I think the same would hold true of steel. We can obtain, in the case of fine wires, strength of the order of 400,000 pounds per square inch in steel, but we cannot obtain any such strength in bars of four inches square in steel. So the fact that the metal is thinner indicates that the base metal itself has a little higher strength, a litle greater density than the thicker base metal.

There is another difficulty we encountered in welding thin sheet metal, or rather, in the preparation of the samples. It occurs in this way (illustrating on the blackboard): If we make a weld in very thin sheet it has a bead, a reinforcement, and in machining off this bead, we did it by the use of an end mill in a milling machine, finding it very difficult on thin sheet metal to machine off this bead to exactly the same thickness as the original base metal.

The tendency, therefore, was for the machinist to leave it a little thicker at the weld; it was difficult to avoid this, and most of the tests on this thin sheet metal, the weld was a trifle thicker, a few thousandths of an inch thicker, than the original sheet, and, of course, where the sheet was only a sixteenth of an inch thick, four or five thousandths of an inch was an appreciable increase in thickness. Therefore, the tendency was for the stress in the tensile test to cause a failure in the base metal outside of the weld, as it did in most cases.

There is a third reason for this. With the larger thicknesses we get more shrinkage than we do with the thinner welds. It goes from the molten to the solid state very quickly, and the shrinkage affects the added metal comparatively little though it may affect the base metal, that is, the thin sheet, more conspicuously than it does in the thick material, causing buckling and warping. But the effect of shrinkage on the added metal is less in the thin weld than in a thick weld having a large deposit.

Mr. T. T. Copeland, Carnegie Steel Co.: We have listened to a very

interesting paper which contains very valuable information to the Welding Society.

The question arises in my mind relative to the welding of coolers for blast furnaces, which is of a cast copper, I presume 97 per cent copper.

In my experience I have found that in a number of welds made in coolers used around blast furnaces, that adjacent to the weld and, in fact, some distance from the weld, it became porous. The process used was acetylene, the cooler was preheated, then welded and then annealed, and under pressure it would show this porous condition.

Mr. Hook: I think any answer that I could give to that would be only of the order of a guess. If that were electrolytic copper that they were using, in other words, if it were a pure copper carrying a small amount of oxygen, I could conceive a reason for such a porosity, but if it were a deoxidized copper, carrying sufficient deoxidizer to take care of the oxygen in the process of welding, I can not see just why porosity would occur.

It may be that the foundry which makes these cooling wedges does use a tough pitch copper which carries a small amount of oxygen. They would likely use that unless another material was specified because the tough pitch or electrolytic copper will give them a casting which will have comparatively little shrinkage and a good surface.

Now, if you take such a material and subject it to a welding heat, particularly if you use a torch, some of the oxygen will be reduced in the metal, and it will be reduced in the sections, which is at a considerable depth below the surface, one-sixteenth of an inch anyway; the hydrogen penetrating there and reducing the oxygen. Of course, the hydrogen unites with the oxygen it finds in red hot copper and forms water vapor. Water vapor lacks the ability to diffuse outwardly. It would be imprisoned, causing pressure inside of the wall of copper which might open up a fracture.

It does not seem like a fracture, it is of a porous condition generally throughout the walls of the cooler, but not so pronounced in the weld. I would like to know if you have experienced this condition?

Chairman Whittemore: Leaks water?

Mr. Copeland: Yes, water leaks under pressure. It is water cooled. They run about ⅜ in. to ½ in. in thickness in the walls, but bottom section runs much thicker.

Those who are familiar with blast furnace work know that the coolers are much larger than the twyers; we do not experience that same trouble with twyers as with the large coolers.

Mr. Hook: Of course, this copper oxide is distributed in small droplets throughout the cast copper section, and a condition which was known in the copper industry as gassing might occur.

Mr. Copeland: Should that be general in foundry practice?

Mr. Hook: Only where a torch acted on it, the flame of the torch

carrying a high percentage of hydrogen. It might possibly occur with carbon monoxide as well.

Mr. Copeland: We found the same condition with the metal arc welding, the customary practice is to preheat before welding, due to the heat conductivity of copper.

Mr. Hook: I would offer one other guess, because that is all it is. I would look into the preheating flame. I remember one case during the war; we had a lot of copper rotating bands which, after the swaging process, were brittle, and it was found that these rotating bands were being heated previous to the swaging of the band onto the shell in a reducing atmosphere, and immediately that the atmosphere of the furnace was changed from the reducing to an oxidizing condition, that brittleness disappeared, and the copper retained its original toughness.

Mr. E. E. Thum, Iron Age, New York: I believe that these coolers are ordinarily made out of phosphorized copper by a brass foundry. I would suggest that on the next repair they be preheated and welded with a copper rod containing an excess of phosphorus or silicon and use a flame that is exactly neutral. Under those circumstances you will prevent a good deal of the excess phosphorus in the casting from burning out, and use a rod which will make a much sounder weld than the ordinary electrolytic trolley wire which the welder might pick up for himself. Welding should be done at a cherry red, and cooled very slowly in the furnace. Then peen the weld and near by with a light machinists' hammer, reheat the casting to a dull red, and cool in ashes. Slight leaks may be stopped by a milky solution of silicate of soda and chalk, applied at a pressure of 100 lb. per sq. in.

Chairman Whittemore: Change the base metal, too?

Mr. Thum: That wouldn't make any difference.

I would like to correct Mr. Hook in one instance. He was discussing the influence of size on test piece. He said he knew of soft wire which would resist 250,000 pounds per square inch. I think he is mistaken. The only iron or steel wire which would develop that would be hard drawn music wire or heat treated wire, either of which is a high carbon steel. Music wire has been hardened not only by excessive cold work, but also by high carbon.

A small wire which would have a small grain, due to excessive cold work, would normally be expected to be somewhat harder and stronger than a larger wire, but this small grain would recrystallize under the welding heat, and consequently welded small wire ought not to be much stronger at the joint than a welded wire of ordinary diameter.

However, we all know that welders generally cannot weld thick sections as well as they can small ones. In other words, a welder who is fairly expert on one-half inch metal could not, for that reason, be expected to do a good job on a locomotive frame, and a welder who could do a good job on a locomotive frame would have some difficulty in making a good long seam in two-inch plate. There is, I believe, a very pronounced influence on size of test piece, especially in the extremes, but

I would judge it would be more a matter of skill of the welder than it would be inherent properties of the metal itself.

Chairman Whittemore: You notice this paper goes back to fundamentals, and gives us the information we need if we want to do work along this line. It doesn't just show you a successful job he has done, or one which somebody else did. He gives the analysis of the alloys he is using and the metallurgical backgrounds. Those are the tools with which welding engineers can work to solve their own problems and push welding ahead.

Discussion paper "How to Test Welds,"* by F. G. Tatnall, Southwark Foundry & Machine Co.

Mr. James W. Owens, Newport News Shipbuilding & Dry Dock Co.: This is a very timely paper, for the industry today is demanding a true evaluation of the physical characteristics of the welded joint, and tests which will determine the competence of the welder.

In my work, I have found that we lack both standard tests for welds and standard methods of testing welders. Even the specimens used in both of these classes of tests are not standardized, and Mr. Farmer's Committee on Standard Tests for Welds has quite a problem before it.

To date, we have been using the standard A.S.T.M. tensile test specimen to obtain the strength of welds, totally ignoring the fact that this specimen was intended for testing homogeneous material. When we introduce, in the center of a specimen, a weld having physical characteristics differing from the remainder of the specimen, we usually test the base metal if the weld is the stronger of the two. The weld, with its higher yield point, is locally stiff and rigid and causes the specimen to behave as if gripped at this point with the jaw of the machine, fracture occurring between the weld and shoulder of the reduced section of the specimen. Because of this, many investigators have attributed failure in this location to the thermal effects of the weld, whereas, in most cases, it is directly related to the shape of the specimen. I have therefore recently recommended to Mr. Farmer that the edges of the standard A.W.S. and A.S.T.M. specimens for butt welds be not parallel, but concave, on each edge, the minimum section being at the weld so as to concentrate the stress at this point and produce failure at the weld. The desirability of this shape of specimen was recently pointed out by J. B. Green, president of the Fusion Welding Corp., and G. Lobo of the Westinghouse Elec. & Mfg. Co.

In testing the welds made by our students during their training period, we use a hydraulic jack equipped with a gage. As our main object is to create a healthy competition between students, great accuracy is not necessary.

Some years ago I developed a method of removing a disc coupon from the completed weld. This test is known as the "plug and ring," and is suitable for obtaining the tensile strength and ductility of the weld and the material in a finished product. It is recommended, however, that

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wherever possible, the qualifying and check tests of the welder be used to judge the strength of the weld in the finished product. Where this is impossible and test coupons are required, the cutting out of such coupons should be discontinued as soon as the customer is convinced that consistently sound welds are being made.

I also developed, some years ago, an adjustable strain gage capable for making measurements from ½ in. to 4 ft., and which could be reset to zero in a similar manner to the instrument described by the author. A gage of this type and the plug and ring testing apparatus are manufactured by the Tinius Olsen Co.

Mr. A. B. Kinzel, Union Carbide & Carbon Research Laboratories: I, too, was interested in the remarks on standardization, both those of Mr. Tatnall and Mr. Owens. Regarding the standardization of the bend test, I should like to refer those interested to the report of the Committee on Bend Testing, A.S.T.M., submitted at the June meeting. Reprints are available. The bend test has been carefully studied, and methods of standardization are suggested, although at that time they were not formally recommended as a tentative standard. We want them to be available to the engineering world for discussion before we do that.

As to the standardization of the tensile test specimen, I am wondering, in the use of a catenary, whether there is concentration of stresses —(illustrating on the board)—even with a comparatively large radius, say four or five inches. It has been the experience in testing that stress concentrations are set up at the edge so that while failure takes place in the weld, the actual pounds per square inch calculated would probably be lower than the pounds per square inch existing in the material. This is a fact that has been well demonstrated on a number of occasions.

It is true that the larger the radius of curvature of the catenary at the point in question, the smaller the effect becomes. Nevertheless, I am in favor of having a small parallel section even though that does mean that, in some cases, the weld can not be tested because of the lack of strength in the plate.

In cases of that kind, other resources are available, such as making the weld of the same welding rod in plate of higher strength. That is, of course, not exactly the same story, but some idea of the characteristics of the weld can be obtained in that way.

Regarding the portable testing machine which Mr. Tatnall speaks of —we had a most interesting time designing it. It is true, as he said, that we have dropped it on a concrete floor and found it had not affected the accuracy of the machine within the limits specified.

Chairman Whittemore: Didn't he say they had to drop it?

Mr. Kinzel: We certainly do not recommend dropping the machine, but it is extremely rugged. It weighs but two hundred pounds. We have made several hundred tests to get it ready for the field, and feel we have something worth while.

As far as cutting out the specimens in the pipe in the field, I am inclined to agree with Mr. Owens—too much of that sort of thing is

detrimental; it certainly does not help the pipe line any. What we have in mind particularly is to keep a check on the welders by coupon tests as well as the occasional cutting out that we may find is necessary.

Chairman Whittemore: Mr. Kinzel, as you know, has done a good deal on this bend specification. There is a good deal of work to be done, unless the last report of the committee clears that up.

Mr. Tatnall: Speaking of standardization, this is my chance to get in a little crack on standardization. I don't know whether you realize that there is practically nothing standardized. Everybody tells me that the speed of testing has a tremendous influence on the results. If you pull a thing an eighth of an inch or a hundredth or two inches a minute, the results will be practically upset, and we find very frequently that such is the case, especially with non-ferrous metals. What are we going to do? Nobody agrees on the tests. Every society has something different. The only specifications we have are that certain tests should be pulled at such and such idling speed of the head of the testing machine which changes. Of course, the minute you start to put on load you stretch everything, slowing down the motor, etc.

We have developed absolutely constant speed movement, but that isn't the solution because other people are coming along and saying the only accurate way is to have constant rate of loading. The load should be applied so many thousand pounds a minute. That is entirely different if you will stop to think a minute. Nobody has decided upon a standard rate of loading. Nobody is convinced as to the method of gripping specimens. They are not agreed as to the best gage length and proper length of the specimens. In fact, I can't think of anything that is really downright standardized at the present moment.

I would like to ask anybody here certain questions. If anybody can tell me the proper speed of testing a weld specimen I would feel that the whole trip out here to Cleveland has been worth while.

Chairman Whittemore: We test them at all kinds of speeds.

Mr. Tatnall: The job of the testing machine manufacturer is certainly a hard one, if nobody knows what they want.

Mr. L. J. Larson, A. O. Smith Corp.: I don't think there is much I can add to this discussion on testing. There is one point in regard to the shape of a tensile test specimen. It seems to me that the shape of the specimen we use depends somewhat on what we are after. In many cases, if we pull a tensile test specimen with a weld in it, and develop the strength of the stock without a weld in it, that is all we want for welds that are made in structures where the reinforcement is left on. If we really want to study the strength of the weld, then we have to resort to some shape of specimen which will produce a fracture in the weld. I think the best method of getting the strength of the weld, at least in heavier stock, is to take a specimen in and parallel to the weld. I can't see that taking the specimen parallel to the weld should cause any error because we have no direction of rolling in the weld material.

In taking the specimen parallel to the weld, we get the actual strength of the material, and also reliable information about the

ductility of the weld. On thin stock it isn't quite so satisfactory. Even on thin stock, however, I think that a specimen taken parallel to the weld, machined down so that most of the material is weld, gives a very important indication. There always is some question, or has been some question in the past, as to whether welding damages the stock. If it does, the damage should be next to the weld, and a specimen cut parallel to the weld indicates the composite strength in that direction, of both the weld and the slight amount of stock that is next to it.

Chas. H. Jennings, Westinghouse Elec. & Mfg. Co.: Mr. Tatnall has given us in his paper, a brief description of a few of the different types of instruments and machines that are being employed in the present-day method of weld testing. He has also mentioned a few points in connection with tests of welds which I would like to say a few words about.

In connection with tensile tests, Mr. Tatnall asks the question, "Why bother about anything but ultimate strength?"

As the reduction of area and elongation of a tensile test specimen are merely measures of ductility, it is altogether possible that this information can be obtained in some other way, thus excluding it from tensile tests. I do feel, however, that in a good many cases, it is of great importance to obtain the static yield point. Many specific examples of the importance of the static yield point can be found in the literature.

G. D. Fish* recommends the use of the following formula in designing welded connections that are subject to dynamic loading:

$$\frac{M+N}{2S_y} + \frac{M-N}{2S_e} = \frac{1}{f}$$

where M and N are respectively the maximum and minimum stresses that are applied to the connection (the sign of M and N being positive for tension and negative for compression), f is the factor of safety against fatigue failure, S_e is the endurance limit for this kind of stress, and S_y is the *static yield point.*

It is readily seen from this equation that the static yield point of a welded joint is of great importance in dynamically loaded welded connections, and must be considered.

Also, I feel that Mr. Tatnall, in specifying only three main types of tests for welds, has omitted one of the most important tests of all, and that is the fatigue test. A knowledge of the endurance limit of welded joints in fatigue is not important in connection with welds that are subject to static stresses only, but it is absolutely essential in connection with welded joints that are subject to dynamic stress. Therefore, I see no reason why the fatigue test has not been included in Mr. Tatnall's list.

Mr. James W. Owens, Newport News Shipbuilding & Dry Dock Co.: Relative to the value of the yield point of the weld, Chief Naval Con-

*See article by G. D. Fish, in August 22, issue of the Engineering News Record, "Specifications for Arc-Welded Connections in Bridges."

structor Malisius avoided the use of welded joints for the longitudinal seams of two 141 foot oil tankers recently constructed at the Deupsche Works, Kiel. The reason given by him was that "a weld made with ordinary electrodes, although having the strength of ordinary structural steel, has very little elongation in the case of overloading," and will fail when the elastic limit of the base metal has been exceeded.*

Chief Constructor Lottman, in an article presented before the German Engineering Societies, and now being published in full in "Marine Engineering," states that the "type of failure and ultimate strengths of longitudinal welded joints are similar to those in the case of riveted connections," even though, as stated by him, the rupture of the weld occurs in such joints at about the time when the piece shows yielding.

In a recent test made by me of deposited metal in which bare low carbon steel electrodes were used, I obtained a yield point of 47,250 lb. per sq. in., or nearly that of the maximum yield point of 51,000 lb. shown by Chief Constructor Lottman in a stress-strain diagram for German S-III ship steel. This matter is brought to your attention as the question might arise on the suitability of welded joints for certain types of structures wherein the joint is subjected to a high longitudinal stress, and to my knowledge no tests similar to those conducted by Chief Constructor Lottman have been made in the United States.

Mr. E. E. Thum, Iron Age: I believe the discussion this afternoon has been somewhat diffuse because it has taken up three different phases of the testing problem which are, in all probability, the jobs of three entirely different kinds of people, and of three different industries.

A certain proportion of the tests described in the principal paper this afternoon was for measuring the stresses in the entire structure. By no stretch of the imagination would that be the job of the welding engineer or the welding supervisor. It primarily is the job of the consulting engineer, or the one who has the most to do with the design and the maintenance of the structure. Assume that a railroad bridge will be built by welding (or by any other system, for that matter). The owners, or the designers, would probably be interested in knowing what the stresses are in that structure when it is completed and under various stages of operation. They would like to know whether a certain redundant member which might have been put in for constructional purposes is throwing a rather high secondary stress in an important member when one side of the bridge was loaded with a heavy freight train.

However, those tests, interesting though they may be, are hardly things that would come within the purview of the welding engineer.

In the second place, we have been talking about other things which are the job of the testing engineer rather than of the welding engineer, namely, the standardization of tests. Speed of a tensile testing machine is something which the welding engineer has no business to worry about. The testing engineer also generally tests small pieces, and, by

*See article by Chief Naval Constructor Malisius in the February 7, 1929, issue of Werft-Reederei-Hafen.

and large, his tests are designed to indicate uniformity of the material as it comes from a mill rather than its adaptability, or the adaptability of the entire structure for the purpose intended.

Then we finally have discussed the third job, which is the important job of the welding engineer, and that is to devise some method of testing the uniformity of the weld and the skill of the welder. Just how that can be done is a question which will require a great deal more thought and experimentation than has been given it in the past, and I believe it would be well for the welding engineer to let the testing engineer worry about such problems as the shape of the tension piece, and let the designing engineer worry about whether an express train at sixty miles an hour is going to over-stress a certain joint in a bridge.

In working on this problem of uniformity of the weld, it would be a good idea to remember a certain principle which the testing engineer tries to adhere to (although he is not successful in every case), and that is that the test should be a measure of the service which is required of the material. It would be foolish, for instance, to estimate the desirability of a chromium steel for a plug gage by the fact that its ultimate strength in tension happened to be 180,000 pounds. The relationship between tensile strength and wear resistance or stability of dimension is so remote that it would be foolish almost to test this chromium steel in tension except that uniform results would indicate a certain uniformity in other properties of lot after lot.

Again, since welds in a pipe line, when they fail, ordinarily fail by tension in cold weather, it is quite proper to test them in tension; but since most structural joints would be designed to work in shear, it would also be proper to test the structural joint in shear rather than in tension.

Finally, and this is something which testing engineers have to worry about as well, welding engineers must remember that practically all service involves stresses of more or less rapid variation in intensity, yet testing is generally done quite deliberately. It is more than possible that a metal or joint which would act beautifully under a slowly applied stress would be disappointing under rapid variation of even a mild stress. Of course, some tests are made for fatigue endurance in order to get some information on this problem, and should be extended, because of the principle that the test should be a measure of the service required. We should not put too much dependence upon a slow test, such as the tension test is.

Of course, a great deal yet remains to be done in developing the art of testing. We don't know yet how to test a rail in a way which will indicate to the railroad engineer whether a particular rail such as a medium-manganese rail is going to give him better service than ordinary high carbon steel rail. His only test is service; he has to put them in the track and see how they work.

A striking instance of the limitations of testing is the failure of the bridge wire first erected in the Mount Hope and the Detroit River Bridges. If there ever was a place where a bridge member or a piece

of metal were to operate under simple tensile stresses, it would be in the main cable of a suspension bridge; yet bridge wire which acted beautifully in the tension test was so unsatisfactory after erection that both bridges had to be dismantled and rebuilt.

To restate my thoughts on the matter, the discussion this afternoon has been involved by considering three different and separate jobs. The thing which the welding fraternity ought to pay most attention to is to develop some sort of inspection and test which will insure the uniformity of welds and the reliability of the welders.

Chairman Whittemore: Mr. Thum has made some very helpful remarks that will help us in our thinking. His colleague, Mr. Smith, was with me on the Mount Hope Bridge in the spring after they had trouble with the wires. We went over to lunch, and he said, "Whittemore, your physical tests for bridge wire are absolutely inadequate."

I said, "Yes, they are."

He said, "The tests of this wire showed it was the best wire that was ever produced for suspension bridges, but experience in service shows that it is no good." The tests were all right, but everything else was all wrong.

Dr. M. G. Yatsevitch, Watertown Arsenal, Watertown, Mass.: I wish to draw attention to a kind of test, which, I think, will be useful and very helpful in the development of welding. That is the hardness test.

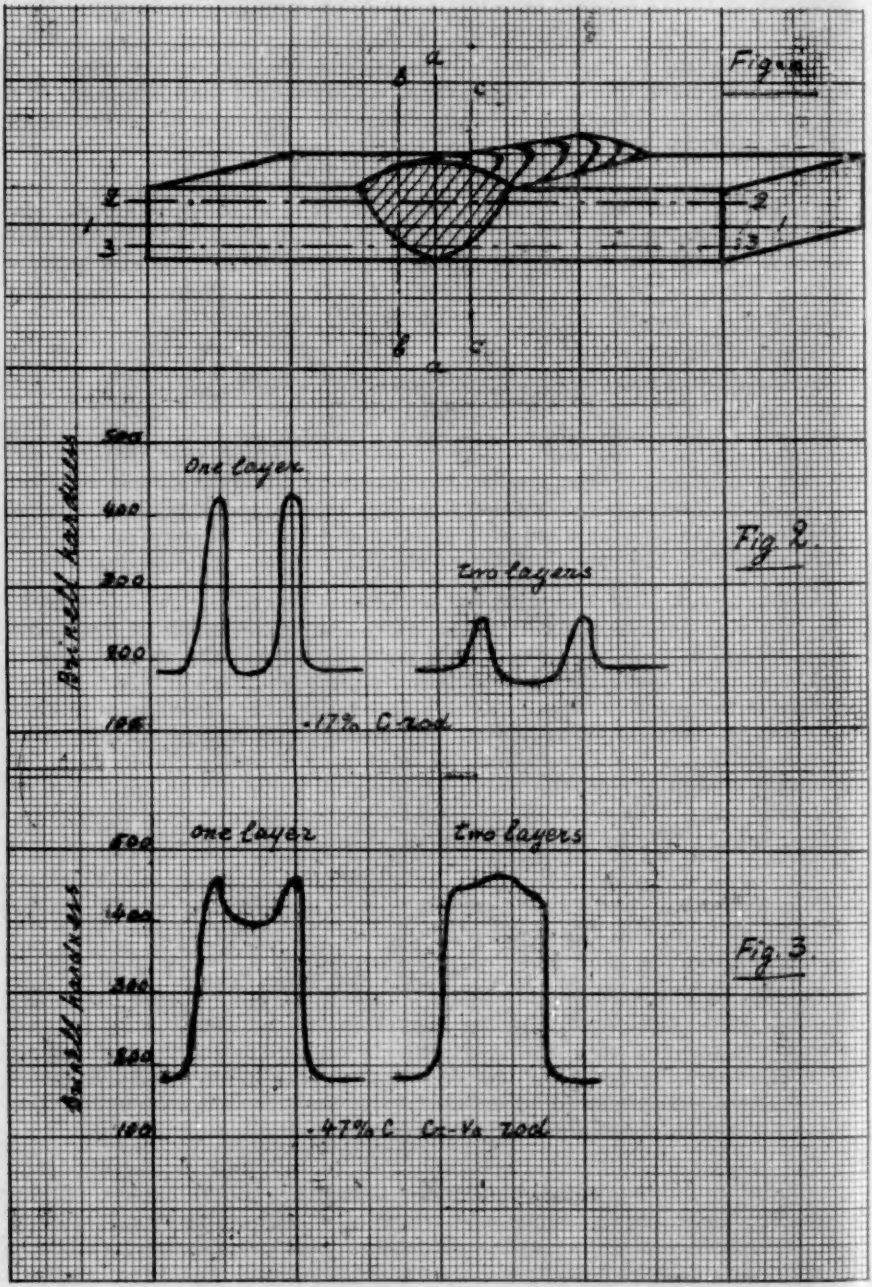
As you know, it is very difficult, or impossible, to test hardness with the usual instruments (Brinell or Shore, etc.) on a small space at points very close to each other; but there is a machine on the market, which appears to be very useful for the purpose: This is the Vickers' hardness testing machine. It allows the taking of hardness at points as close to each other as 1 mm. By making, so to say, "a hardness survey of welds," I have obtained with that machine some very interesting results from the point of view of judging the qualities of the welds and also from the point of view of getting an insight into the processes taking place during the formation of the metal of the weld.

The method of testing is simple:

A small piece—about 3-in. long and ½-in. wide—(the length depending on the extent of the heat affected zone, which can be established by light macro-etching with Nitric Acid)—is cut out from the welded joint transversely to the direction of the weld (Fig. 1) and the larger cut surfaces are made smooth enough usually by grinding with a Norton Emery Wheel No. 60 on a surface grinder. Such specimens are easily prepared in a short time and are not expensive; the surfaces are very suitable for macro-etching.

The cross section of the weld obtained in this way is surveyed for hardness in different directions: depending on the thickness of the plate, the weld may be surveyed horizontally in the directions 1-1, 2-2, 3-3, etc., and vertically in the directions a-a, b-b, c-c, etc. (Fig 1). Now, if you take the hardness values obtained and plot them against

distances, you will get some very interesting results, showing the changes in this property of the weld, which can be correlated with



other physical properties, metallographic structure, thermal and metallurgical conditions of formation of the weld and with such welding characteristics as penetration, fusion, composition of welding rods, speed of welding, current conditions, etc. To illustrate this, suppose we have an ordinary butt weld. If we survey it for hardness in a horizontal direction and plot the values, we shall obtain a curve something like that on Fig. 2. The left values are characteristic for the plate, then comes a rapid tremendous increase in hardness, characteristic of the transition zone, where the metal of the plate is mixed with the metal of the welding rod. After this follows some fall in hardness with the values more or less characteristic for the welding rod, and then on the other side of the axis of symmetry of the weld we shall have a symmetrical repetition of the previous curve. Taking into consideration the usual non-homogeneity of the weld, the symmetrical appearance of the plotted curve is very striking. The general picture is very characteristic for all welds, but, for instance, for each different kind of welding rods (other conditions being constant) there will be a particular type of curve. If we have a soft rod with about 0.17 per cent of carbon, the hardness curve will have two high jumps at the sides and a very low middle part. But in the case of a chrome vanadium rod with carbon about 0.47 per cent, the curve will have the appearance shown on Fig. 3.

Suppose we have the case of a weld made of one layer and after putting on another layer with the same rod we compare the corresponding hardness survey curves for both welds. The result will be this: the sharp peaks on both sides will be very prominent for the one-layer weld, but they will appear much lower and more rounded after the application of the second layer (Figs. 2 and 3). If in the first case the variations in hardness values from the plate to the peak were from 185 to 400, in the second case they will be from 185 to 250, which is considerable and shows very well the advantages of putting the second layer. The second curve on Fig. 3 refers to a two-layer weld made with a chrome vanadium rod, and its shape can be well associated with somewhat self-hardening properties of the metal. . . . The correlation of similar effects of different welding conditions on hardness curves with the quality of the weld may be a subject of a very useful study, having important practical results. To a certain extent this is being done by us at the Watertown Arsenal, and I hope soon to have results available for publication.

Chairman Whittemore: It helps in selecting the welding rods and technique?

Dr. Yatsevitch: Yes. Suppose you have a weld with very sharp and high peaks. It usually breaks easily, having bad penetration, though the X-ray picture promised good results. If you have a weld where the hardness goes up gradually—the peaks are rounded, fusion (transition) zone is extended, and the central part of the zone approaches the level of the plate hardness—then you have very good work.

Chairman Whittemore: Can't use it to qualify welders yet, can you?

Dr. Yatsevitch: I think we can. In this respect as in many others,

the consideration of results of the hardness survey of longitudinal sections of welds is also important and useful.

Mr. Kinzel: We have done the same thing with the same degree of success with an ordinary Rockwell. We have taken readings so as to cover the whole weld.

Chairman Whittemore: I think that is a development I haven't heard of. It would be a pretty good thing to follow up. I didn't know you have done anything with the Rockwell. We have found somewhat the same curves, but we haven't applied it to the welding rods.

Mr. Kinzel: We have done the same thing with the micrographs as well. All of these instruments, however, are scientific laboratory tools, and are not taken out on the job very readily.

Chairman Whittemore: Don't need to have them polished. Then, of course, there is the relation—I don't know that it holds for weld metal —that the ultimate tensile strength is proportionate to the hardness so that that would give a pretty good idea of the strength. Of course, for a given alloy you can have an idea that you get a certain tensile strength; probably your ductility will be the same.

Mr. Ernest Lunn, Pullman Car & Mfg. Corp., Chicago: I have gotten some interesting results with a scleroscope, especially in connection with welds on cast-iron.

Chairman Whittemore: It depends on whether you get some contradictions, and have to go to a better method. The Rockwell is all right. On tubing you have to cut out your sections and block them up. With the Vickers you don't need to worry about that because you measure your indentation afterwards in the same way that you measure the indentation on the Brinell.

Mr. Lunn: You cannot always use the Vickers as conveniently as the portable one.

Chairman Whittemore: You have to take the one that you can use more conveniently, depending on how accurately the results must be for your work. I told Mr. Spraragen that more ought to be brought out on testing. Everybody thinks the chemical and the metallurgical laboratory have everything their own way. They don't come as near duplicating service conditions as the materials testing laboratory. There hasn't been anywhere near the amount of study of the mechanical testing methods since the Civil War that there has been on chemistry, X-ray and some other methods of testing. This has been a sort of lost child that nobody has bothered about, and I think they would well repay more study and effort.

WEDNESDAY AFTERNOON, SEPTEMBER 11, 1929

J. J. CROWE, Presiding.

Discussion paper, "Study of Nitride Needles,"* by P. Alexander, General Electric Company.

Chairman Crowe: You have all heard this most excellent paper, and it is now open for discussion.

Dr. Walsted, Massachusetts Institute of Technology: Not being a member of the Welding Society, I appreciate the opportunity to enter into this discussion. Unfortunately, I can't entirely agree with the speaker. In research work, we wouldn't get very far if we were all me-too-Peteys, would we?

In stating that these needles were due to oxygen, one bit of contradictory evidence, I believe, is the heat-treating in and out of solution of the needles. Oxides, I don't believe, are capable of being heat-treated in and out of solution at will. Moreover, if the needles are an oxide, you would expect to have some evidence of their presence in the unetched condition.

Oxides, I believe, form more readily at the grain boundaries than at the cleavage planes. The needles shown in this paper were for the most part in the cleavage planes. In working on nitriding during the last two years in the laboratory of Dr. Homerberg, at the Massachusetts Institute of Technology, we have been placing in our furnaces samples of Armco and electrolytic iron, and subjecting them to nitriding treatment with ammonia along with the steel known as nitralloy. The Armco and electrolytic iron show the formation of these needles which, I believe are identical with the needles shown by the speaker. Those needles respond to etching and heat-tinting in such a way as to indicate that they are nitrides. They respond to the sodium picrate etch in the same manner as carbides, and have, in the past, been mistaken for some form of carbide by several investigators. They respond to heat-tinting in such a way as to indicate they are not carbides. X-ray patterns show the introduction of a new material which we have not yet determined, but which we believe to be nitride.

Another bit of evidence in contradiction of this paper is the reduction of the oxide by ammonia. In the introduction of nitrogen in the Armco or electrolytic iron, the contact of the ammonia with the heated iron causes a dissociation of the gas into hydrogen and nitrogen. That will give you nascent hydrogen and nitrogen. In order to introduce nitrogen into iron, it is necessary to have nascent iron or nascent nitrogen. In the same furnace atmosphere, in contact with the heated iron, then, you will have also nascent hydrogen. Assuming for the moment that the needles obtained by the work of Dr. Homerberg and myself and the needles obtained by the last speaker are identical, it seems to me impossible that they could be due to oxygen, because of the fact that ammonia alone was introduced into the fur-

*Paper published in September, 1929, issue Journal of the A. W. S.

nace. Ammonia was swept through the furnace for considerable time before the heat was turned on to sweep out the air. Specimens which had been slightly colored with superficial coating of oxide (slightly blue), were introduced into the nitriding furnace and the oxide was found to be reduced. The specimen came out of the furnace with the characteristic nitrided surface. Under those conditions, then, where the oxides are actually reduced by the nascent hydrogen, I don't see where it would be possible to form those needles, if it were due to oxygen.

The removal of the needles by hydrogen was mentioned. Some years ago that work was done by several investigators. It was found, on heating in hydrogen steels containing nitride needles, that it was possible to remove those needles completely, due to the formation of ammonia. Gases analyzed as they came from the furnace showed the presence of ammonia, the hydrogen actually combining with the nitrogen in the steel.

The question, of course, is quite away from settlement yet. The last speaker has presented a very strong argument. However, I can only add my bit of evidence in the other direction.

Mr. J. C. Lincoln, Lincoln Electric Company, Cleveland: I am sorry I can't discuss this paper on its merits. A good many years ago I was interested in producing ductile welds by means of the carbon arc, and I started in by making photomicrographs. As far as I could determine, the photomicrographs said this metal ought to be ductile, and when I tried to bend it, it would break. I decided that the photomicrographs didn't tell me the story they ought, and thereafter I did not depend as much on photomicrographs as I might have done and as a good many people do.

I have had the notion that possibly something occurs in the arc which has to be interpretative, and when you make photomicrographs of metal that has been arc-deposited, it is impossible to interpret those photomicrographs in the same way that photomicrographs are properly interpreted when the steel is made in the ordinary manner. Whether that conclusion is correct or not, I am not prepared to state, but in particular cases that I was interested in it was apparently true.

Anyhow, in order to get rid of brittle metal, with the carbon arc, it was necessary to get rid of oxygen in the atmosphere around the arc. That I have demonstrated to my complete satisfaction. Consequently, I am prepared to believe that in the formation of these needles, if the needles are indicative of brittleness, that oxygen had something to do with it, but, as I say, that is very poor evidence from a technical standpoint. From a practical standpoint, it is important.

Mr. James W. Owens, Newport News Shipbuilding & Dry Dock Company: Some years ago I did considerable work on the effect of heat-treatment upon nitride in welds, not doubting the nature of the needle-like structure, as a sample of deposited metal submitted to the Bureau of Standards for test showed that the percentage of nitrogen varied from 0.038 to 0.142. This investigation can be found in my book,

"Fundamentals of Welding," page 211, in the *Welding Engineer* of April, 1921, and in the *Railway Electrical Engineer* of May, 1921. The first indication that I had that these needles were not nitride, was a paper by Mr. A. H. Goodger on "Red-Shortness of Weld Metal" presented before the Institution of Welding Engineering, London, June 22, 1927, and published in the *Welding Engineer* of February, 1928. In this paper the author records a test wherein he made a weld in an oxygen atmosphere, using a covered steel electrode, and he found that the structure of the deposited metal was a mass of fine needles. As a result of this investigation, Mr. Goodger came to the conclusion that the "needles themselves consist of extremely thin films of oxide separated from a solid solution on annealing along the cleavage planes of the iron grains. Their formation can be prevented and welds made which are definitely not red-short, by the use of electrodes incorporating suitable deoxidizers."

Regardless of the nature of these needles, a metal arc weld can be forged and their presence does not necessarily mean that the weld metal will have low ductility, for when a weld is made in a series of layers it is possible to obtain an extremely ductile deposit due to the annealing action of each layer. I recently deposited a pad of metal about 6-in. long and 1-in. square, using a bare low-carbon steel electrode. A round specimen cut from this section gave a yield point of 47,250 lb., an ultimate strength of 60,600 lb., a 20 per cent elongation, in 2 in. and a reduction in area of 22.3 per cent. Of course, results such as this cannot be obtained when the weld is deposited in one layer.

Professor G. E. Doan, Lehigh University, Bethlehem, Pa.: I should like to ask Mr. Alexander, in the first place, whether these needle-like structures might not be the sections of plates, of nitride or oxide deposited in the crystallographic planes of the grains. As they appear on the screen, it seems that that might be the case.

I would like to ask him, too, whether he has determined the quantity of oxygen, chemically, which this iron contains before it shows such needles or plates. That would be very helpful in determining whether or not it is oxygen and whether or not it is nitrogen, because from the equilibrium diagram of iron-nitrogen and iron-oxygen, we should be able to determine whether there is such a eutectic as would show these needles exist.

I want to ask him further what explanation he gave for the appearance of these needles after the weld had been made in Argon which he supposed to be free from oxygen; and finally, I want to express extreme admiration of the paper—for it is just this kind of careful, scientific work in welding which, although it won't give us the complete answer, as Mr. Lincoln has said—won't tell us whether the metal will be strong and ductile—nevertheless, coupled with other investigations of physical properties and chemical properties, it will be extremely useful, and we could not get along, in the end, without that kind of work.

Mr. R. W. Holt, Chicago Steel & Wire Company: "The company I am

with has been doing quite a few experiments to produce ductile welds in thin sheet steel, and for welding in general. The result of this work, which I worked on for quite a few years, is what we call the Carb-O-Flux process. In this process, the metal is very thoroughly protected with fluxes against both oxygen and nitrogen of the air. Under these conditions we do not find these needles, and the metal is very ductile. I just want to offer this for what it is worth in line with the papers and discussions that have been presented."

Mr. Harry P. Coats, Firestone, Akron, Ohio: I am not a member of the Society, but I should like to ask a couple of questions.

This is an extremely valuable paper. I came in because I thought it was going to be proved that nitrogen was the cause of the brittleness of this structure, and I am quite amazed that it appears not to be nitrogen, but oxygen, and I am quite well convinced that that is true.

I should like to ask Mr. Walsted if he made the so-called McQuaid-Ehn tests on Armco iron and the electrolytic iron to see if they already didn't contain sufficient oxygen to give these needles.

The explanation of the question that was just asked by the professor from Lehigh, "why did the needles occur in the Argon?"—I think the speaker, Mr. Alexander, stated that he started out with oxides in the electrode.

Now, we must examine our material because if the oxides are already present, either in the electrode or in the metal, and gets in the weld, the deposited metal, of course, is going to have these needles; and then another point was brought up: hydrogen reduces oxide, and, therefore, it can't be oxide; otherwise annealing in hydrogen would reduce the oxide.

These oxides are not normal oxides which we see in unetched specimens. That is prominent evidence from the appearance of the micrograph and so I think we should remember that this is oxygen in another form, entirely different.

Chairman Crowe: It seems to me that there is another question which may be involved in this whole business; that is, we are trying to draw a parallelism from work carried out at low temperatures with the results of work carried out at the temperature of the arc, up in the region of 3600 deg. C.

The time is growing close to the hour allotted to each speaker, and I am going to ask Mr. Alexander if he cares to reply to the discussion at this time.

J. P. Walsted: Someone asked if Dr. Homerberg and I had made any tests for abnormality on the nitrided electrolytic and Armco irons. As we were doing experimental work on nitriding and these pure irons were used only as control samples, we had no occasion to run abnormality tests. The conditions of our experiments made it certain that the needle structure we obtained was due to nitrogen.

Chairman Crowe remarked that in the discussion, comparison had been made between the low-temperature nitriding process and the

high-temperature arc-welding process. This is true. However, other factors than temperature should be considered. In nitriding the reagent is ammonia which breaks down in the presence of iron at a comparatively low temperature to give nascent nitrogen which is taken up by the steel. In the arc-welding process we have the molecular nitrogen of the air which is broken down into atomic nitrogen by the electric arc. Both the nitriding process and the arc-welding process produce nascent nitrogen under conditions favorable to its absorption by the steel. So you see the two are not as widely separated as it would at first appear.

Mr. Alexander: I do not remember all the questions, but I will attempt to answer what I can.

First of all, the question of Professor Doan about the possibility that these needles are plates. I agree with Professor Doan that they are more likely plates than needles. I think that the investigation conducted by the metallurgists of the Bureau of Standards years ago proved conclusively that these needles, irrespective of their nature, are plates and not needles. We simply call them needles because of force of habit.

The second question is about the amount of oxygen necessary to produce these needles: I have made a few attempts to determine the amount of oxygen necessary to produce these needles, and although I have no definite information yet, I may state that a very small amount is sufficient to produce these needles, if they are not numerous. The amount is so small that the presence of these needles, or the amount of oxygen that forms them, will not very materially affect the ductility of the weld.

The next question as to whether oxygen is already present in the plate: to settle this question, I subjected the plate used in this experiment to identical tests, and I was unable to discover the needles in the plate itself. Therefore, I agree with one of the speakers that a very high temperature is necessary to produce these needles. I also agree with another speaker that it may be an entirely different form of pure iron oxide. (Applause).

Discussion paper, "Chemical Reactions of the Carbon Arc,"* by G. E. Doan and E. Ekholm, of Lehigh University.

J. C. Lincoln: I have read the paper by Professor Doan and Mr. Ekholm with great interest and would say that the results obtained in this paper are confirmed by work that I have done myself.

Part of the work that I have done with the carbon arc has been done in a shielded atmosphere in which the air was excluded from the space around the arc. In addition, means were provided whereby a limited amount of steam was introduced into the space around the arc. The steam was broken down by the hot carbon and a quite powerful reducing atmosphere resulted. The evidence of the atmosphere

*Paper published in September, 1929, issue Journal of the A. W. S.

being reducing was that at the end of the work there would be a pop when the outside air mixed with the atmosphere around the arc when the welding device was lifted from the work. I have made no chemical analysis of the gases around the arc but would say that in addition to probably a considerable amount of CO in the atmosphere there was an appreciable quantity of hydrocarbon because the gas escaping from the enclosure burned with a yellow flame. In my work, therefore, the oxygen of the air was excluded from the arc and in place of an oxidizing atmosphere a reducing atmosphere was produced.

Professor Doan is apparently of the opinion that the oxidation of the carbon evaporating from the carbon electrode was the means by which the carbon was removed from the weld metal. The work that I did would indicate that no carbon is included in the weld metal even with a reducing atmosphere because the resulting weld was very soft and nearly as ductile as the original steel. I am handing around for inspection some of the welds made in this way and you can see for yourself the extraordinary ductility of the resulting weld. Further than that you will see that the sample which is enameled is enameled over the weld just as well as over the original steel. From these experiments I have concluded that the carbon evaporating from the electrode does not enter into a chemical combination with the steel and the only way to get carbon into the weld metal is to mechanically touch the melted weld metal with the carbon electrode.

Actually in the work I have done I was unable to find any hard spots of any kind, but Mr. Doan points out very pointedly that with a very short arc the melted weld metal will come in contact with the carbon electrode with the result that carbon is absorbed by the steel. In the work I did the voltage varied from twenty-four to thirty volts; the amperes were about two hundred and fifty to three hundred; the length of the arc under these circumstances was about three-sixteenths of an inch and the resulted weld is, I believe, a demonstration that no carbon was absorbed by the steel under these circumstances.

I had hoped that Professor Doan was going to get some data as to why there should be a crater with a carbon electrode. He points out the fact that a crater with a carbon electrode resembles the crater produced by a gas-welding torch, and a very extraordinary fact is that apparently there is a strong blast of gas from the tip of the carbon electrode which strikes the weld metal with force enough to depress the surface of the weld metal in some cases as much as three-quarters of an inch. This would mean a hydrostatic pressure equal to nearly six inches of water. This phenomenon has not had the attention it should have had from investigators of the arc. As I pointed out in a paper published in the *Welding Journal* two or three years ago, if a hole is bored in the positive terminal of a carbon arc, this blast of gas is projected through the hole in the positive terminal and can be examined more in detail. Measurements indicate that as much as two-thirds of the energy of the arc is absorbed in producing this blast of apparently vaporized carbon. In ordinary welding operations, of course, this blast of what is apparently vaporized carbon heats the positive electrode and is the source of most of the heat which appears

at the positive electrode. I hope that someone will be induced to make future experiments with the carbon arc with a hole through the positive electrode and make a further study of the extraordinary blast of white, hot gas which appears under these circumstances and see if we cannot get a further knowledge of what really happens in the electric arc.

Chairman Crowe: I fear that Mr. Lincoln is leading the discussion toward physical chemistry, where we have chemical reactions at high temperatures involved. As I understand it, vaporized carbon may or may not carburize iron, depending upon the temperature, pressure and other conditions. I believe Professor Doan will tell us more about that later.

I wonder if it would make it clearer, Professor Doan, if you would give us the chemical reactions that occur in the carburization and decarburization of the metal.

Professor Doan: Carbon ordinarily exists in steel, as you all know, in the form of Fe_3C. That carbide may be dissolved in excess amount of iron, or it may free, as Fe_3C. Or it may be there as graphite, but the most simple reaction that we can imagine for the carburization of steel would be 3Fe plus C equals Fe_3C.

As I recall without looking it up, the heat of formation of Fe_3C is small but positive. I think Professor Boylston could tell us about that. I think, like most other inter-metallic compounds, it has a small heat combination. So the tendency to form would probably not be great. In carburizing steel you bury a piece of steel in carbon and heat it. The higher the temperature the more rapidly this reaction takes place. At room temperatures it does not take place at all. At high temperatures the depth of the case increases very rapidly. So we have qualitative evidence to lead us to believe that this reaction would increase in velocity with rise in temperature.

The oxidation reaction would be pretty much the reverse, without balancing it, depending on whether you have an excess of oxygen or not. Fe_3C plus O_2 equals FeO plus CO. That also increases in velocity with rise of temperature.

Mr. Lincoln's example of the carbon arc being drawn from the copper ring may be somewhere nearly a parallel case, but I think the conditions are so different that we would not be warranted in concluding, because he can get carbon deposits from this six-inch long flame drawn under those conditions, that there is also carbon in all of the envelope around the incandescent tip of the electrode. His second assumption, namely, that there is zero affinity or negative affinity of molten iron for carbon at high temperatures, is counter to the thermo-chemistry of this reaction, and, while it may be so, we are not justified in assuming it as correct. If anyone has any comments or discussion as I go along, I would be very glad.

Professor Doan: There is one comment on Mr. Lincoln's measurements that I would like to make. That is, that the passage of the stream of water through these anode coppers, in order to measure,

as I understood it, the heat in the flame, would most likely give him erroneous results.

It is well known that the most of the heat in any arc occurs at the electrodes, and not in the flame. By this method the water circulating through that copper anode would measure principally the heat generated at these copper tips, and not at all, in my opinion, the heat in the flame.

Mr. M. R. Taylor, Lincoln Electric Company, Cleveland: May I ask what voltage you used?

Professor Doan: We had to keep our arc length constant, and our current constant, so we used whatever voltage was necessary to drive that current through an arc of that length. The voltage wasn't, we considered, as important as the other two.

Chairman Crowe: I would like to ask Professor Doan from where does this oxygen molecule come? We think of this envelope as being composed of CO and CO_2.

Professor Doan: This is the incandescent carbon tip itself; then, if we are going to assume that there is some carbon vaporized, let us call that the carbon envelope; certainly outside of that there is a CO envelope, and then a mixture of CO, CO_2, nitrogen and oxygen, which has diffused in from the air. (Illustrating).

Chairman Crowe: You don't think it is just the decomposition of the CO_2 itself?

Professor Doan: The CO_2 has formed from the atmospheric oxygen.

Chairman Crowe: That might be decomposed CO and free oxygen.

Professor Doan: It is a question how quickly that carbon, while it is in passage, finds oxygen atoms to combine with and form CO or CO_2. As Mr. Lincoln says, it may be that the CO and CO_2 out here, by being suddenly cooled, may be decomposed and form carbon.

Mr. K. L. Hansen, Milwaukee: I regret very much that I did not have Dr. Doan's paper come to my attention a good deal earlier than I did. If it had, I would have prepared a real discussion. As it is, I will make only a few brief remarks.

Yesterday afternoon Dr. Doan happened to pass our booth over in the exhibit, and I believe he became rather interested in the flame that we produced with a combination of carbons. For the past year I have been working on the development of an electric or arc torch, but, unlike Mr. Lincoln's torch, I feel we are getting somewhere with it commercially. As is usually the case, this development came about as the result of some specific problem that arose. We had one customer who desired to braze the rotor bars of squirrel-cage induction motors and the bars were brass bars which he decided to braze on to copper-end rings. The ordinary carbon arc does not apply at all to brasses or bronzes that are rich in zinc, because the zinc goes out too rapidly and leaves a very brittle material. So, in endeavoring to work out this problem we experimented and finally found that we could fair-

ly well control and direct an indirect arc in such a manner as to produce a flame that could be used for brazing.

After some experiments we arrived at a combination in which the positive electrode consisted of two carbons. Viewed from the top and end, they appear as shown in Fig. 1.

It will be noticed that an approximately semi-circular crater is formed at the ends of the carbons.

The negative carbon, which is smaller in diameter than the positive carbons, is inclined at an angle of approximately 75 deg. to the positive electrode and its pointed end is located approximately at the center of the semi-circular crater. Viewed from the side, the positive and negative electrodes appear as shown in Fig. 2.

The flame is seemingly emitted from the negative electrode and projected downward past the positive electrode. The flame thus produced can be used for actual commercial work.

We found that it worked very well on non-ferrous metals. On ferrous metals there was a tendency to burn the metal, and I think

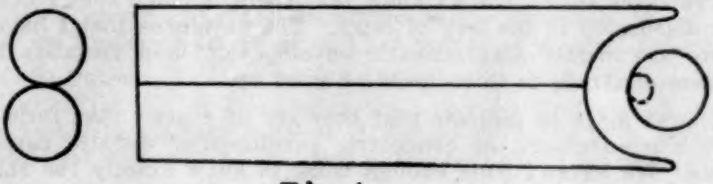


Fig. 1

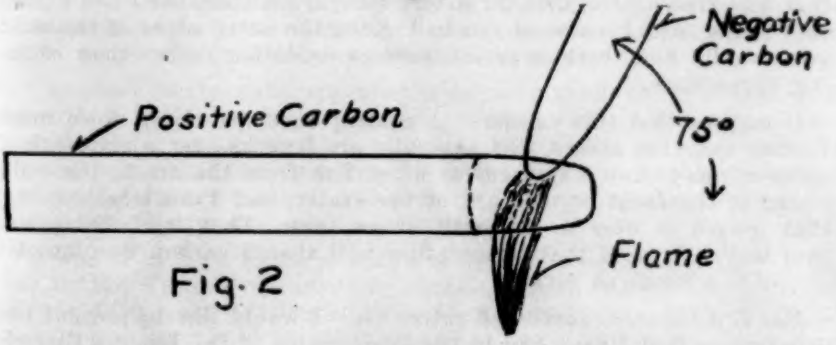


Fig. 2

Fig. 3

Showing crossection of positive carbon with aluminum core

that was due to the oxygen present in the flame of a carbon arc, as brought out in Dr. Doan's paper.

Now, later, our further experiments led to another construction which works decidedly better. Instead of using two carbons for the positive electrode, we have reduced it to one, with a narrow section in the center, as shown in Fig. 3.

The purpose of the narrow section in the center is to facilitate the forming of the crater as the carbon burns off comparatively faster in the narrowed-out section. Then, by introducing an aluminum rod, we get a flame which is much steadier and quieter. Also, when we use it on steel, we get very much better results, probably because the aluminum helps to reduce the amount of oxygen in the flame. Spectrum analysis taken of the flame shows that the oxygen lines have almost entirely disappeared. That seems also to harmonize with the point brought out in Dr. Doan's paper, that if the oxygen can be removed from the carbon arc, you can get very much better results.

The torch is in operation in our booth and we shall be very glad to show it to anyone who is interested.

Professor Doan: I don't know that there is much that I can add to the discussion in the way of reply. The envelopes that I have drawn there are merely diagrammatic envelopes to help visualize how the carbon electrode is worn away or used up.

I don't mean to indicate that they are of exactly that form or that they are envelopes, or concentric envelopes of definite carbon contents. We haven't done enough work to know exactly the shape and contour of those envelopes. It is quite possible that in this envelope that was drawn here, that the exterior is carbonizing, but I don't think that is the case, because if you look along the outer edges of the weld, you usually find there is severe surface oxidation rather than reducing appearance.

It may be that this carbon-rich central envelope comes down much further than the others. At any rate, arc lengths over a sixteenth of an inch don't show any transfer of carbon from the arc to the weld, either in the front or the back of the crater, and I don't believe that that length is over a sixteenth of an inch. That is, I do believe that molten iron at that temperature will absorb carbon very quickly if any is present as such.

Mr. E. Chapman, Lincoln Electric Co.: I would like to present two experiences that I have had in the laboratories of the Lincoln Electric Co.

Professor Doan associates the reduction in size of the carbon electrode during the operation of the arc with the appearance of carbon in the welded metal. It has always seemed to me that the carbon electrode consumption was due to the atmospheric oxidation taking place at the high temperatures of the electrode. In an attempt two years ago to reduce the rate of electrode consumption, I made some cored carbons. The cores consisted of the silicates and fluorides of potas-

sium, sodium, calcium; any of the commoner arc-supporting materials, the notion being that if the temperature of the emitting areas could be lowered, the whole electrode would operate at a lower temperature. On test, this assumption proved to be true; the cored electrodes having a consumption of about half that of an uncored carbon.

Another point that is very pertinent in the operation of a carbon arc and to which Mr. Stewart has alluded is the direction of the arc blow. Professor Doan mentions that the arc blow in his experiments was backward. I have found this to be a very badly oxidizing arc condition. The resultant metal has small particles of oxide scattered through it and, what is worse, presents grain boundaries that are fairly loaded with minute oxide particles. If the direction of the arc blow or flame is disposed ahead of the portion being welded by suitable magnetic means, the weld metal will be uniformly clean.

I think that is one of the facts that has been overlooked and I think that it would contribute to the suggestion that the oxygen of the atmosphere is or can be blown through the weld metal thermally.

Discussion paper, "A Metallographic Study of Some Metal Arc Welds,"* by Professor Boylston, of Case School of Applied Science.

Mr. J. R. Dawson, Union Carbide & Carbon Research Laboratories, Long Island City, N. Y.: Discussing the paper by Professor Boylston and his associates is easy because it seemed to me to be a very fine paper and one with which very few differences could be made.

One thing in regard to the microphotographs: We have found with gas welds that etching for structure is much more satisfactory with ammonium per-sulphate than the reagents described in the paper. That might be something to try out on the arc welds.

The photomicrographs appeared to be very good, to have been well taken and well reproduced. One thing that I don't believe was referred to, in my observation of microphotographs of arc welds—it seemed to me that the weld metal is made up with a groundwork of a decidedly columnar nature, and that the Widmanstättian structure is superimposed over the columnar structure.

It was of interest to me to notice that, in this paper, and also in the one by Mr. Tatnall, the recently suggested bend testing was referred to, and some tests were made along those lines. Some history of that matter perhaps would be of interest.

A little over two years ago, at the Union Carbide Laboratories, information was desired about the ductility of welds, and this was particularly to compare the weld metal obtained from two different types of welding rod. For this, what is called the American Welding Society Bend Test, was used. The results were erratic, and really led to nothing. We all agree, I think, that the elongation over the weld in the regular A.S.T.M. flat tensile piece does not have much

*Paper published in September, 1929, issue Journal of the A. W. S.

meaning, so Mr. W. B. Miller, in continuing those experiments, developed the bend test, where the specimen is treated as a beam bent near the ends, which are then forced together to produce bending in the weld, and the measurement is not of the angle of bend, but of the elongation which has been produced. That seemed to him to be a real measure of ductility.

Then, further study of this matter was made by Mr. W. B. Miller and Mr. A. B. Kinzel. The results of their work were published in two papers: "The Bend Test As Applied to Welded Coupons," by W. B. Miller, JOURNAL of American Welding Society, September, 1927, and "A Critical Study of the Bend Test As Applied to Iron and Steel," by A. B. Kinzel, in the TRANSACTIONS of the American Society for Steel Treating, November, 1927.

Later on, there seemed to be urgent need for some means of evaluating welds, particularly as used in pressure vessels and boilers. The Welding Subcommittee of the Boiler Code Committee, and the American Welding Society were attempting to get together to find a means of permitting welding, and still controlling it so that it would be safe.

As a contribution toward the source of this difficulty, Mr. S. W. Miller and Mr. Kinzel worked together and produced the formula set down in Professor Boylston's paper. The formula provides a means of rating welds and determining what stresses are allowable in welded joints.

Chairman Crowe: Mr. Dawson is trying to make your paper controversial, Professor Boylston.

Is there any discussion applying to this last paper?

Professor V. N. Krivobok, Carnegie Technical Institute: Professor Boylston is quite right in saying that very little is known on the science of metallography in relation to welding. I was much interested in the study he has made in the Case School of Applied Science, and I hope he will continue his work.

He, of course, dealt with arc welding. During the last year or so quite a bit of work has been done—you can judge from about forty pages of work here—on resistance welding, entirely studying the results of that welding from the metallographic point of view, and some of the conclusions which are incorporated in the microphotographs here, are quite interesting. They are different from the results which Professor Boylston obtained, but, of course, he was dealing with one kind of welding, and we were dealing with another.

A few questions of theoretical interest, but nevertheless of the nature which might bring about important commercial considerations, are as follows: In the arc welding Professor Boylston tells in his paper, he does not find the origin of enlarged grain size.

In the arc welding where we have a liquid metal deposited on cold metal, there must be a heat gradient, which to my mind should result in the enlargement of grain. We know that in commercial welding, the welds often break, not in the weld, but just outside the weld, and

I examined those welds which broke that way, and it was invariably in the region of the large grain size.

I was much interested in Professor Boylston's study of the adjacent metal. He finds the presence of nitride needles. How those nitride needles could get there I don't know. If they are there, it is most interesting. Why should we pick up nitride from the air which would form a compound of some sort with iron to form nitride needles?

I was also quite interested in the structure which Professor Boylston described as doubted structure, and I think I may attempt to say what it is.

I believe it is a very finely dispersed gas, and looking as it does, at very high power, sometimes as high as three thousand diameters magnification, I came to the conclusion that they are very fine, shall I say, holes, which to my mind are caused by the presence of these gases.

In regard to our own studies, metallographic studies of welded parts, of resistance welding, we have found that right next to the weld there exists always the area of large grain size produced, of course, by the excessive heating.

We have tried to heat treat the welded bars in order to see if the heat treatment will not result in improvement, or perhaps in making it worse. We found that although the structure is considerably changed by the heat treatment, yet the mechanical properties of the bars in question, and those bars of low carbon steel, did not change very much.

Once more I wish to voice my appreciation of the start of the work in the very important field, and that is, of the science of metallography as related to welding.

Mr. C. K. Stewart, Westinghouse Electric & Manufacturing Company: I would like to confirm Dr. Krivobok's work in connection with this area of enlarged grain structure next to the refined grain structure. We have been doing some metallographic work at Westinghouse—research that we are not yet prepared to publish—but I can say in that connection that we have found this enlarged grain structure in between the refined zone and the welded metal. We have found this in a number of welds, but in some welds we have been unable to find it, and as yet are not entirely able to account for its disappearance in these particular welds.

Mr. Spraragen: I would like to ask Professor Boylston a question on conclusion three. He says: "The combination of high temperature and short arc appears to give the best ductility of all (bend test) and the highest allowable working stress, which is rather surprising."

What I would like to ask about is, why the "which is rather surprising?"

Professor Boylston: It surprised me; perhaps it did not surprise anyone else.

Normal temperature and short arc, I had supposed, would be the conditions which would give the best commercial results. We were rather surprised to find an apparent improvement on increasing the arc temperature.

Chairman Crowe: I am surprised that some of our statistical friends haven't taken exception to the results in Table II, where there is a matter of differences of four hundred per cent or more, and on those observations which differ from one another by four hundred per cent, conclusions have been drawn on a basis of approximately ten per cent.

Mr. Ernest Lunn, Pullman Car & Manufacturing Corp., Chicago: I have been quite impressed with Table No. II, showing the relation between HS 31, 32 and 33, and LS 51, 52 and 53 results.

The figures would indicate that high currents with short arcs give by far the better results. No one would ordinarily work with a long arc for any length of time, but some are somewhat skeptical about the use of high-current densities.

I would like to ask the author whether that is the conclusion that he draws from these figures.

I notice that the yield points are practically the same and the ultimate strength about the same, but the elongation in eighteen inches is so much higher in one case than in the other that it makes the use of relatively high-current densities of great value for a great deal of work.

Professor Boylston: That is what makes it surprising. They were higher temperatures than were considered normal.

Mr. Lunn: There is no skepticism in regard to being accurate?

Professor Boylston: Conclusion No. 3: "The combination of high temperature and short arc appears to give the best ductility of all (bend test) and the highest allowable working stress, which is rather surprising."

The reason we used this bend test is because the ordinary elongation measured in the usual way did vary so much. I gave them in Table II simply to show the variations.

Mr. Lunn: Is there any doubt in your mind but that these figures could be reproduced again?

Professor Boylston: I don't know. We took these specimens.

Mr. Lunn: The results are so startling, as you say, that the meaning is quite significant, if it is probable that they could be reproduced. My own experience indicates that they are correct.

Professor Boylston: I hope you will understand, gentlemen, that we were trying to measure the physical properties of weld metal only, but in making the tensile tests, the base metal part of the bar elongated in some cases more than the weld metal, and that throws out not only the elongation as measured by the increase in length of the test specimen, but the yield-point. We ignored those results, and the

bend test as applied to weld metal only had then to be determined. We machined away all the base metal and produced a bend test bar consisting of nothing but weld metal.

Answering Dr. Krivobok's question as to lack of large grain size due to thermal gradient, I have just been talking with him, and I think I have the answer to that. His remarks apply to cold-rolled or cold-worked material in which you would expect that subsequent heating at some temperature would produce considerable grain coarsening at the region of critical stress, but we were working with hot-rolled steel.

Mr. James W. Owens, Newport News Shipbuilding and Dry Dock Company: Professor Boylston's conclusions are in agreement with those reached by many of us. As well known, I have been an advocate of the use of higher-current densities in arc welding so as to primarily insure consistent fusion with the base metal and to increase production. The General Electric Company has also recently, I believe, come to the same conclusions, although some years ago their general attitude was to recommend the use of the lower-current densities.

When the higher-current densities are used, the metal flows faster and the operator has a tendency to maintain a long arc. It, therefore, becomes necessary to specifically call his attention to this and the necessity for using a short arc. When one considers the excellent welds produced on automatic machines with the higher-current densities, it would seem to indicate that the same conditions can be secured by manual welding if we control the arc length. The normal arc is longer for coated and covered electrodes than for bare electrodes but is largely taken care of by the protection afforded the molten metal by the flux.

One of the speakers pointed out that in some cases he had found that a large grain size existed in the fusion zone and in other cases a small grain size was found. This is a detail that needs to be checked to see whether the small grain size obtained was not due to the annealing action of subsequent layers. Tests made by me indicate that the annealing action obtained in a multiple layer deposit improves the metal in both the deposited and fusion zones. It is hoped that the Fundamental Research Committee in redrafting their program as a result of some of the bad tests obtained by Professor Thornton, will take into consideration the various points reached by Professor Boylston in his paper. The reduction in porosity by the use of a short arc should be given careful consideration in any tests conducted to determine the cause of porosity in welds.

Mr. H. M. Hobart: In the interests of historical accuracy I must correct Mr. Owens. In both Schenectady and Pittsfield, metal arc welds were made in the year 1918, using much larger currents than had, to my knowledge, ever before been employed anywhere.

In a contribution to a paper entitled Welding Mild Steel, which I presented at a meeting of the A.I.E.E. on February 19, 1919, Mr. R. A. Wagner contributed the following table of results of some tests he had

made in Pittsfield on ½ in. thick tank steel plates using current strengths ranging from 80 to 300 amperes:

Amperes	Tensile Strength in lb. per sq. in.
80	37,000
125	50,000
150	57,000
180	63,000
220	66,000
275	62,000
300	58,000

In the minutes of the meeting of the Welding Research Subcommittee of the Emergency Fleet Corporation, held on December 19, 1918, I refer to having supervised the metal arc welding of a ¾ in. thick steel plate using 400 amperes. The welding rod was of about ¼ in. diameter.

I fully agree with Mr. Owens that large currents should be used in metal arc welding. Eleven years ago, in October, 1918, I made a report which is published at pp. 228 to 232 of the 1918 Transactions of The Society of Naval Architects and Marine Engineers, in which I called attention to the "very great improvement in all the mechanical characteristics with increasing current." I was analyzing the results of a series of metal arc welds of ½ in. mild steel ship plate which had been made in many shops under the supervision of our committee and with many different systems (ac and dc) and with many different kinds of electrodes. We had allowed each welder to employ whatever electrodes and kind of current (ac or dc) and amount of current he preferred. In the following table, the results for all the welds made with currents between the limits of 150 and 175 amperes are averaged in Column A, those with 105 to 145 amperes, in Column B, and those with 83 to 94 amperes, in Column C. The greatly superior results with the larger currents are seen in the Table.

	A	B	C	Ratio of A to C
Current	158	123	89	1.78
Ultimate Strength (lb. per sq. in.)	59,000	50,000	46,000	1.28
Per cent elongation in 2 in.	8.9	6.2	5.0	1.78
Torsion-torque ratio	0.86	0.75	0.67	1.28
Bending angles in degrees	54	45	32	1.68

One hundred and seventy-five amperes now seems small for use in welding ½ in. thick mild steel plates, but in those days I was severely criticized for advocating the use of such high and higher current values.

Mr. Owens: I did not say that the General Electric Co. had not used the higher current densities in some of their earlier work. What I did say was that this company did not recommend until comparatively recently, the use of higher current densities.

Mr. Hobart: I said that anywhere near as large a current as 350 amperes was never used for welding an arc anywhere in the world until long after that happened in Schenectady.

Chairman Crowe: Any other discussion of either Professor Boylston's paper or previous papers?

Professor Boylston: I think I ought to add that in our paper we were not trying to prove the nature of the needles in any way. We made no tests to determine their nature. I used the well-known name that has been given them for want of something better. I do not mean to go on record as believing that they are nitrides or anything else in particular, I merely wish to describe them somehow.

Chairman Crowe: I think we all understand that.

Mr. P. P. Alexander, General Electric Co.: I would like to ask Professor Boylston if he has observed in his work the presence of nitride needles in low carbon steel, not subjected to welding. Of course, they could be present only in very low carbon steel. In my experience, I have found in only one case the presence of nitride needles in very low carbon steel, which was sent to the laboratory for some special examination. Those particular samples were found to be brittle, in spite of the low carbon, and a metallographic examination showed the presence of nitride needles.

You see, I am using the word "nitride" because, until my experiments are checked up by a number of investigators, it is not right to use the new name in place of the adopted one.

Professor Boylston: I have never run across them in low carbon base metal.

President Llewellyn: At the risk of repeating a remark I made this morning, I would point out that this is a highly specialized subject. I recited this morning the difference between a specialist and an all-round man. My experience has been along the all-round line. A specialist is one who knows more and more about less and less, so that at the limit he knows everything about nothing. The all-round man is one who knows less and less about more and more, so that at the limit he knows nothing about everything.

Without claiming any detailed knowledge on the very interesting specialized subject that is before us, I would like to venture into this specialized field to point out that one phenomenon that has been referred to this afternoon is not dependent upon metallurgy for a clear explanation at all. At least, so it seems to me. I am not underrating the value of metallurgy, and metallographs. I appreciate them highly, but several times this afternoon reference has been made to the fact that in testing a welded specimen, the specimen frequently breaks outside the weld, in the base metal, and it has been suggested that some metallurgical difference in grain growth next to the weld is responsible.

Whether or not grain growth has anything to do with it, I don't know —I am quite prepared to accept the verdict of specialists on that point —but the fact that fracture so frequently does occur outside the weld, can be explained much more simply.

In the specimens which I have inspected, the fracture occurs too far away from the weld to be explained by grain growth. Most of the fractures have been an inch or an inch and a half away, and I think they can be explained—if I may use the blackboard—very simply.

Here is your specimen. (Illustrating) Here is the weld. It is well known that while the ultimate tensile strength of ordinary weld material may be slightly below the ultimate tensile strength of the base metal, the yield point of the weld metal is considerably higher than that of the base metal. We commonly put the yield point of structural steel at approximately 50 per cent of the ultimate. It may run a little higher than that. Whereas the yield point of weld material reaches three-fifths, or even four-fifths, of its ultimate strength.

Now, what does that mean in a testing machine? Let us draw a picture of the specimen after you have passed the yield point of the base metal. The base metal out here (illustrating) will be necked as a result of its elongation, it will decrease in area. You don't need metallurgy to explain what is going to happen. You have a smaller area at the necked point. Of course, it will break in the necked base metal (indicating) before it will break at the less necked weld. (Applause)

Chairman Crowe: There seems to be only one fault with Mr. Llewellyn's illustrations; some of the investigators have shown lower elastic limit for welds than we have been getting.

Mr. Owens: That is one reason we should use a catenary curve.

Chairman Crowe: Any other discussion?

Professor Boylston: I think if you will examine my figures 4, 5 and 6, you will see some conditions similar to the one that Mr. Llewellyn has put on the board. These pictures have been reproduced on a somewhat small scale, but that is precisely the reason I left out any consideration of the yield point figures which are included in Table II only as a matter of record. We have no thought that they might represent the yield point of the weld metal itself. It is for the same reason that we discarded the elongation test and depend upon the bend test.

Chairman Crowe: Any other comments?

Mr. Dawson: If I remember correctly, in the theoretical discussion of this column-like bend test by Mr. Kinzel, one thing that he found necessary for correct results was that the specimen should be at least three times as wide as it was thick. As I read this paper, I don't believe the bend test specimens were that wide in this case. Perhaps Professor Boylston may have overlooked that point, or maybe I didn't read the paper correctly.

THURSDAY MORNING

September 12, 1929

PRESIDENT F. T. LLEWELLYN, Presiding.

Discussion paper on "Non-destructive Testing of Welds with the Stethoscope and X-Ray," * by C. O. Burgess, A. B. Kinzel and A. R. Lytle, Union Carbide & Carbon Research Laboratories.

President Llewellyn: I think, gentlemen, we have heard the be-

*Paper published in September, 1929, issue Journal of the A. W. S.

ginning of something we have been waiting for these many years. The meeting is now open for a very brief discussion of this subject.

W. P. Kellogg, Portland Oxygen & Hydrogen Co., Portland, Ore.: Does the method apply to cast iron as well as steel?

Mr. Kinzel: We never have tested any cast iron welds, as we were not particularly interested in cast iron. However, my guess would be that you can do it perfectly satisfactorily.

Mr. H. H. Lurie, Purdue University, Lafayette, Ind.: How about Monel welding? At times there are cracks in the welds. If you could find out before a great deal of work is done on the tank, it would save money.

Mr. Lytle: I don't see why you can't find defects in a weld by the use of the sound because a defect gives the passage of sound through the structure.

Dr. St. John, New York: It may be of interest to you to know that the perfect dub at first crack picked out three defects on the test the first time he tried it. I was the dub. I hadn't attempted it before. I read the manuscript, had a problem of my own on which I wanted to apply the method, and asked permission to see and hear the method work. I was shown a sample of the plate in which I was told there might be some defects. I saw Mr. Kinzel go through the motions with the stethoscope attached to his ear, and attached them to my ears, and I think it was in the first five minutes that I picked out one, two, three places, and he said they were the places where the trouble lay. I believed him and I didn't demand that they produce the X-Ray negatives, but I did notice there were certain yellow reference marks on the other side of the plate, which, I presume, were their marks by which they identified the places in question.

With respect to its use on other materials, I can see no reasons why it can not be applied to welds in almost any kind of material, as long as you have some of the sound material of the same kind with which to get a preliminary comparison of the way perfectly sound material listens. It is rather hard to talk about how sound materials sound. We have to change our terminology here for a moment.

I can see no reason why it should not apply equally well to aluminum, Monel metal, copper, steel, cast iron—almost anything else.

Mr. Ernest Lunn, Pullman Co., Chicago: I should like to inquire whether the stethoscope could be used successfully to locate blow holes in steel castings?

Dr. St. John: I would like to know that myself. As a matter of fact, that is the next thing I have on my list to try out because, as a great many of you know, I do a considerable amount of work in the examination of steel castings by X-Rays, and so can check up the acoustic test.

Mr. Kinzel: That which is heard in the stethoscope is not a matter of sound transmission, but a matter of characteristic harmonics, if you will, emanating at the instant the material is struck. For that reason I see no limitations in the way of various materials. Blow holes in cast

iron present a very different type of problem. They are generally very much larger than anything we deal with in welds, and generally occur at changes of section where differences in characteristic sound may be expected due to difference in change of section as well; thus somewhat complicating the situation. However, from the work we have done, I should say that it is well worth trying. We will follow the work with interest and, if desired, give what assistance we can.

Mr. H. H. Lurie, Purdue University: I would like to ask the authors what area must the defects contain before the defect can be detected? What is the size of the pinhole, slag, pockets, etc., that can be detected by this method, or must there be a series of them before you can find them?

Mr. Kinzel: That question brings up the general problem, Can one test for general porosity of a weld by means of stethoscope? I don't believe that one can detect very small pinholes, or minute slag inclusions, which have very little effect on the ultimate strength of a weld. Moreover, unless critically located, it is most improbable that isolated pinholes have any great effect on the ductility. We believe that when we find a spot with a stethoscope it is sufficiently serious so that its effect will be shown, either in the ductility or tensile strength test. This means that there must be a difference in physical properties of the order of 5 per cent or more; and I think the way to answer your question is not directly by telling you the actual number of size or number of holes or particles necessary for detection, but rather that the defects which affect the physical properties more than 5 to 10 per cent are determined.

Mr. Burgess: That doesn't mean that the X-Ray does not detect porosity. We were able to find porous sections of a weld very easily with the X-Ray, although they were barely discernible in the specimens after pulling.

Mr. Kinzel: I should like to supplement Mr. Burgess' remarks regarding the porosity on X-Rays. We undoubtedly find porosity with the X-Ray. However, we are not sure from the X-Ray of the exact state of distribution of the holes, so that the use of this test, to replace, for example, an oil test under rather high pressure, while possible, is not definitely recommended by us at this time. It is something you will have to experiment with and find out yourself; but it has potentialities.

Mr. T. T. Copeland, Carnegie Steel Co.: What is the greatest thickness of metal that can be X-Rayed and show the defect, lamination and defect castings?

Mr. Kinzel: We have worked up to one and a quarter inches, that being the limit of our interest at the present time. I understand that Dr. St. John has done considerable work on many heavier sections. I will ask him to further reply.

Dr. St. John: For what I consider routine commercial examination, an exposure of half an hour is a limit. Beyond that the operation becomes very expensive. With the X-Ray tubes at present available on the market, working at a safe load, it is possible to get satisfactory

pictures through three inches of steel, under those conditions, and to get indications through three and a quarter or possibly three and a half inches of steel, using the technique that is suggested in this paper, going diagonally parallel to the scarf. If the scarf is at 45 deg., that means that the actual thickness of the plate which can be examined under these circumstances would be about two inches, because the thickness through which the X-Rays would have to be penetrating would be then slightly under three inches, so that the working limit for this type of X-Ray inspection would be a plate two to two and a quarter inches thick.

President Llewellyn: We would like to devote the whole morning to this subject, but it is impossible. We have two other papers. It has been announced that Mr. Burgess has films that he will be glad to display after the meeting. Will Mr. Burgess arrange to do that in Room No. 2, right opposite here, at twelve o'clock? I suspect there is going to be quite a demand for stethoscopes.

Discussion paper on "Welding Studies at the Watertown Arsenal," * by Major J. B. Rose, Ordnance Department, U. S. A.

President Llewellyn: We are wonderfully indebted to Major Rose for this wealth of data and information which might well serve to occupy the whole morning. Unfortunately, we have obligated ourselves to vacate this room at noon for other purposes and we shall have to postpone discussion.

I now take pleasure in asking Professor J. Hammond Smith, of the University of Pittsburgh, to speak on "Stress Strain Characteristics of Welded Joints." Following Professor Smith's talk, we will adjourn to Room No. 2, where the very interesting instrument that he used will be displayed and explained.

Professor Smith gave a résumé of his prepared paper. (Applause)

Written Discussion of paper on "Welding Studies at the Watertown Arsenal."

Dr. H. H. Lester, Watertown Arsenal: The building up of structural units from rolled plate by forming and welding is a development that has come to stay. The welded structure is more dependable than the usual casting because it contains fewer hidden defects. Dependability is an exceedingly important characteristic for building materials. The engineer must know what he can depend on in strength and durability. The casting as usually made might be good and when it is good it may be very good. But it may have within it, and in a vital section, a crack, shrink cavity, blow hole, or other gross defect. The engineer has felt that there are, in the case of castings, possibilities of sinister weaknesses and possibilities of failure in vital parts.

The welded structure meets this objection to the casting because the possible weak spots are confined to the welds and these usually may be

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distributed where they will be least dangerous. There remains, it is true, an element of doubt as to the soundness of the weld.

Major Rose has pointed out how this last element of unreliability may be minimized and perhaps largely eliminated. That is radiographic control of welding technique permits the development of a proper welding method for each particular job. He has shown that this developed practice can be transferred from the experimental to the production weld, and that the production weld is as good as the experimental one. This is of tremendous importance. It means that the last element of uncertainty may be eliminated and that the engineer may have definite assurance as to probable performance in service.

There are other features in this radiographic control. Welders are held to a high order of performance. They are forced to keep their minds actively on the job, they are forced to think. Their skill develops rapidly, or else they show, very soon, an inaptitude for the work.

With welders trained in this way, it should soon become unnecessary to X-Ray the production welds except occasionally, and then more for the moral effect on the welders than for the purpose of detecting flaws.

In the opinion of the writer the application of radiographic control marks a real advance in welding practice.

THURSDAY AFTERNOON

September 12, 1929

C. A. ADAMS, Presiding.

Discussion paper on "Non-destructive Test of Welds," * by Elmer A. Sperry.

Chairman Adams: Mr. Sperry is not here, but I believe that Mr. Drake of his company, is going to present the paper.

Mr. Drake presented Mr. Sperry's prepared paper.

Chairman Adams: I am going to ask Mr. Drake, for the benefit of those who haven't this paper in hand, if he will describe very briefly the detector end of the apparatus.

Mr. Drake: We pass heavy current through the specimen and have two ways of detecting the flaw. In the first method we pick up by actual contact the voltage drop, and where the current is forced to go around the flaw, it gives us an increase in unit potential. The other method does not necessitate contact with the specimen by the pick-up device. There are two pick-up units which are actuated by the flux surrounding the member. This flux is uniform as long as the axis of current is not disturbed. However, if there is any discontinuity in the metal the axis of current is displaced and this, in turn, disturbs the flux around the specimen, giving a resultant electromotive force in the pick-up circuit.

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In both the above cases we used audion tubes and amplified it considerably to operate our recording equipment.

Chairman Adams: Being an electrical man, I am going to add just a word to Mr. Drake's explanation of the magnetic pick-up method. There are enough electrical men here to appreciate it.

The current is uniformly distributed throughout the cross section of the rail; the magnetic field will be transverse, or at right angles to the rail. There will be no longitudinal component of that magnetic field, but if the current is deflected, there will be a transverse component of the current at the point of deflection, first in one direction, and then in the other. The pickup device is a little magnetic circuit, with its magnetic axis parallel to the rail. Therefore, no transverse flux around the rail, due to the uniform longitudinal current will link with the yoke. But any transverse component of the current will produce a longitudinal magnetic field which is picked up by this little yoke-piece, and while it is moving through this longitudinal field, it will generate an electromotive force in the coil surrounding the yoke, first in one direction, when it passes across the deflected current, and then in the other direction, when it passes back again.

We will take up the discussion on Mr. Sperry's paper. I am going to ask Mr. Obert, who has been very much interested in this problem for a long while, to open the discussion.

Mr. C. W. Obert, Union Carbide & Carbon Research Laboratories: I think we can all agree that we are very much interested in the possibilities of the Sperry process. The Sperry process has been used with marked success in testing steel rail heads and it has come to our attention in the welding field quite recently. It has come to my attention more particularly since interest in the testing or exploring of welded joints for pressure vessels has become more acute. We have heard, through various sources during the early part of the year, that certain manufacturers of pressure vessels were undertaking to solve this problem of the strength and soundness of the welded joint by means of either the Sperry process or some method of magnetic exploration, which was very gratifying, as it has been thought by the Boiler Code Committee members for a great many years that what is holding back the development of welding in this country, particularly in so far as the codifying of welding practice is concerned, has been the lack of a satisfactory non-destructive test of a weld.

The state and municipal inspectors, as well as the members of the Boiler Code Committee, have often said that if an apparatus could be produced that could explore the weld and find what the condition was inside without destroying the structure, there would not be much difficulty in assigning an equitable and safe working stress to any particular kind or type of a weld. Up to the present time, however, this is the first method of analysis of welded joints that has given any real promise of quantitative results. The magnetic method analysis has been talked of here and experimented with to quite some extent abroad, but from all that I have been able to learn, the experiments with it on welded joints have not shown sufficiently definite results to make it

appear very promising. A corporation in the vicinity of New York has accomplished some very interesting results in the magnetic exploration of homogeneous materials such as plate and structural material and it is to be hoped that they may be able to extend their studies to welded joints. If the Sperry process can be made a practical tool for use in the tank and structural shops and when applied to the various forms of welded construction, will succeed in showing what we need to know about the welded joint, I think it is very safe to predict that not only the Boiler Code Committee and the allied regulatory bodies throughout the country, but also the building departments and authorities in control of structural work will welcome it and use it as a basis in determining the values that may be safely allowed for stresses on welded joints. I, personally, am very strong in the belief that the negative attitude which the regulatory bodies have shown toward welded construction in the past, has been due largely to the absence of such a method of analysis.

Just at the present time the Boiler Code Committee is in the process of revising its Unfired Pressure Vessel rules, which revision will take quite a step toward the goal that this Society has been working for so long. When you have the opportunity to read and examine these revisions, it should be borne in mind that they have been made and authorized without the benefit of any such method of analysis as the Sperry process, or its equivalent, and that if you have objections to the remaining limitations on welded vessels, you should understand that it is some such form of analysis as this which would give the Code Committee just exactly what information it needs to work out a more adequate and equitable set of rules for the stresses allowable. With such a means of measurement and test, I see no reason why there should be any limits at all on size or working pressure of welded pressure vessels.

I certainly believe that I am expressing the joint views of not only the Boiler Code Committee, but also of the officers of this Society in commending Mr. Sperry for this excellent paper. I hope that he will see to it that not only the welding fraternity, but everybody interested in the pressure vessel field, is not only kept informed on developments, but also given every assistance in applying this method and bringing it up to its highest possibility.

Mr. James W. Owens, Newport News Shipbuilding & Dry Dock Co.: The two papers presented today on the non-destructive tests of welds clearly show that considerable progress has recently been made in the development and application of welding. Tests of this character have been badly needed in order to advance the art on a sound scientific basis, and with such tests we can look forward to a rapid application of the welding processes, not only to unfired pressure vessels, but to steam boilers and structures wherein the failure of the welded joint would mean a loss of life and/or the destruction of property.

In addition to the non-destructive tests described today, it is understood that another non-destructive test is in use in Germany. This test consists in placing an electro-magnet on one side of the joint and

blowing iron filings on the reverse side. The soundness of the weld is indicated by the distribution of the filings. This test was described in a welding symposium at Lehigh University about a year ago by Dr. Kane, on his visit to the United States. As outlined at the time, the test appeared to be very simple and might even be made more practical if it were possible to confine the filings in a receptacle, and it is recommended that it be given consideration along with these other tests.

Mr. Philip Swain, McGraw-Hill: Mr. Sperry does not make clear in his paper exactly how his method is applied to the testing of welds, and I hope this will be explained more fully in a written addition to the discussion. I think many will be interested to know how the brushes are placed in relation to the rough surface of the weld.

Mr. Drake: The figure I refer to in the paper shows the adaptation of the method to a welded drum. There we have a series of brushes held by fairly heavy spring pressure and there is relative movement between these brushes and the drum. The pick-up unit is mounted on the brush holder midway between the two sets of brushes, and as long as the metal passing between the brushes is homogeneous no current is generated in the detection device. However, any separation in the metal passing between the brushes interrupts the current flow and results in an induced current in the pick-up unit.

Chairman Adams: There is perhaps one more part to that, Mr. Drake. Mr. Swain referred to the roughness of the weld surface. I think he would like to know whether or not it is necessary to smooth that down mechanically so as to avoid irregularities which might give misleading indications.

Mr. Drake: The device, in its present form, is capable of locating small inclusions if the weld is smooth. Now, as the roughness of your weld increases, the minimum size of the inclusion which may be located, increases.

Mr. Swain: May I ask you another question? Is the line of brushes, take in the case of longitudinal weld in line or pipe, is the line of brushes along the line or perpendicular to it?

Mr. Drake: Along the line.

Mr. Swain: Would it not be possible to work it the other way at right angles?

Mr. Drake: We have tried it both ways; it will work either way.

Mr. Swain: It would be possible to put the brush line at right angles to the weld and straddle the line so none of the brushes touch the weld?

Mr. Drake: The brushes do not touch the weld, but straddle it.

Mr. E. R. Fish, Comb. Eng. Corp.: I would like to ask whether the apparatus has been reduced to such shape and proportions that it can be readily used in the boiler shop? A boiler shop is a pretty rough place, in which it is difficult to use delicate instruments. Has it been put in a practical shape for use in a factory?

Mr. Drake: I would say it has. There is not a great amount of

difficulty in getting your boiler to it. You would have the equipment in your boiler shop at one end, and when you have welded the boiler, send it up and pass it through the inspection. The inspection process does not take long. The only objection to having it right out in the factory is the fact that you put very heavy current through the weld, and it means low voltage, heavy current generating equipment. It is not easy to transmit that current around the plant.

Chairman Adams: The most expensive part of the equipment altogether, it is safe to say, is the generator, because low voltage generators are inherently expensive. They are all commutator and brushes.

Mr. J. W. Owens: What are the values of the currents used?

Mr. Drake: We run from about three hundred amperes per square inch up to five hundred.

Chairman Adams: That is per square inch, and of course in the brushes on the side, it spreads to quite a large area and a matter of ten thousand amperes altogether and perhaps more.

Mr. Woofter: I would like to ask whether you use direct or alternating current.

Chairman Adams: Direct entirely. AC wouldn't work for this purpose.

I am going to depart from the job of chairman for a moment, and discuss the subject a little bit myself.

We are just on the doorstep, as it were, of a new field of development. We had presented this morning a method of combination of two methods, the stethoscope and the X-ray methods, of examining welds nondestructively. We have just had an account here of another method to accomplish the same result.

Mr. Obert mentioned the magnetic analysis method. In a few words, I am going to describe that method.

Two exactly similar coils are placed around, we will say, a boiler tube, or any steel tube, and it is to that type of weld, or material, that this device is particularly well adapted. The two coils are in series electrically and magnetically. There are two exactly similar secondary coils surrounding them, connected in opposition. An alternating current is passed through the primary coils which produces a magnetic flux, longitudinally, in the air space inside of the tube itself to some degree, but much more in the metal of the tube, if it is magnetic steel.

There will also be secondary currents circumferentially around the tube wall. If there is any difference in either magnetic or electrical condition, in the two portions of the tube under these two coils, there will be a difference of electromotive force induced in the two secondary coils, and that difference, or residual, is observed either by a galvanometer of some kind, which gives merely the value of the differential voltage, or, preferably, on an oscillograph, which gives the actual differential voltage as to its wave shape, amplitude and phase. It has been found that the shape of this differential wave, its amplitude and its phase, are all indicative of certain conditions in the metal of the

tube. Analyses have been made on tubes which were afterward examined by metallurgical processes, and the diagnosis made by this analysis—I am speaking now only of things that I know—checked very closely with the metallurgical examination.

We have, then, these four methods; each one has its advantages and disadvantages. Each one has its limitations. It would be rather difficult, for example, to apply this last mentioned method to a boiler drum two inches thick, or three inches thick and four feet in diameter—not impossible, but very difficult. Moreover, so far as the circumference of the drum is concerned, it would not differentiate between one point on the circumference, and another in the same transverse plane, but would give you the total in that transverse plane, and you couldn't tell where, in the circumference at that point, the defect was located.

There is another limitation which applies in a different way to both this magnetic analysis method, and the Sperry method. If, in the magnetic analysis method, the defect is on the inner wall of a very heavy tube, it will not show up as plainly as if it were on the outer wall, for the reason that the skin effect, the tendency to drive the current to the outer wall of the tube, produces a much higher current density in the outer wall—I am speaking of secondary current—than it does on the inner wall. Also, in the Sperry method, if you have a defect, for instance, in a rail, down at the foot of the rail, and your exploring apparatus is along the head of the rail, a little deflection of the current, way down at the foot of the rail isn't going to produce anything like as much effect upon your detecting apparatus as it would if it were up at the head.

Fortunately, for the railroads, the defects in the head are the common ones. That is where they almost always start, and this apparatus works perfectly for that job, as nearly perfectly as I can imagine anything working.

Now, when it comes to the application of this method to boiler drums, for example, you have there, also, some differences in the magnitude of the indication, as between a defect on the inner wall of a heavy drum, and on the outer wall.

There are cases where the application of the Sperry method to complicated structures, H-beams, angles, etc., would be very difficult. There are cases where the magnetic analysis method would be very difficult. There are cases where the X-ray examination would be very difficult, particularly when the thickness of the part to be investigated exceeds a certain point. There are differences in portability of the apparatus, differences in expense, and weight, but the interesting and promising, cheerful part of the picture to me is the fact that we have made a start, and that sometime these limitations that I have mentioned can be overcome by a reasonable display of ingenuity and knowledge of the science of the subject. In fact, they are being gradually overcome, first in one place and then in another, and I am sure that we are coming to a time in the not distant future, when in all of these vital structures (by that I mean structures in which we must get nearly perfection), we will have some method of determining with a very con-

siderable degree of accuracy or definiteness, whether or not the job is good enough for the purpose in hand.

WRITTEN DISCUSSION

Mr. J. H. Critchett, Union Carbide & Carbon Research Laboratories: The welding industry is to be congratulated that an engineer of Mr. Sperry's technical ability and past accomplishment has become interested in one of our most annoying problems, that of satisfying regulatory bodies and other engineers, of the integrity of welded structures. The degree of interest in this question that is being shown by people not actively engaged in welding is the strongest kind of confirmation of the increasingly important part welding is taking in industry.

That the development of satisfactory methods for non-destructive testing of welds will be of the greatest help in increasing the rate of development of the welding industry, no one will deny. Availability of such tests will place our industry in a better position, from an engineering point of view, than the cement industry is today, and quite conceivably better also than the riveting industry. Both of these methods of construction seem to have grown to their present size despite lack of the type of test of the completed job that is now being demanded of the welding industry.

Also, there is undoubtedly place for more than one type of test. That is, a method which would be quite satisfactory for proving in the field welds used in the erection of a steel building, might be entirely unsuited to proving in the shop welds in a pressure vessel such as a boiler drum. The latter service seems to be of the type where Mr. Sperry's apparatus will most immediately prove valuable. It is hoped that by the time of our next meeting we may have from the author of this paper another contribution giving more specific data derived from the use of his apparatus in testing welds.

It would be interesting to know the type of indication given by different faults, such as lack of adhesion, poor penetration, and laps and porosity. Also, the effect on the sensitivity of the instrument of varying thicknesses of reinforcement, heat treating effects adjacent to the weld, especially when welding alloy steel, and the applicability of the system to different types of welds, such as lap, fillet, and butt.

The known important success of the method in studying transverse fissures in rails gives assurance that it will be a valuable aid to the welding engineer. Our thanks are due Mr. Sperry for turning his unique originality and engineering ability to help the welding engineer, and we look forward with high expectation to important results.

Dr. S. Specht, Magnetic Analysis Corp.: The paper from page 48 to page 59 deals principally with the well-known non-destructive method of test on rails. The wiring diagrams, diagrammatical representations, photographs and reproductions accompanying the article have also been discussed in the past and are also known.

From page 60 on, regarding the application of aforementioned method to testing of welds, is too much generalized and technically insufficient for an intensive study to warrant a positive discussion.

However, I might discuss one factor which I believe is of great importance and should not be overlooked. I do not think, and can verify my objection, that Dr. Sperry's method is in any way analytical. By that I mean I do not believe it possible for him to separate between properties as transverse cracks, longitudinal seams, segregations and welded properties in an upset state. Stated differently, I do not believe that the results obtained by this method are quantitative as well as qualitative.

The magnetic method of test employed and developed by myself and the Magnetic Analysis Corp., respectively, is just what the words "Magnetic Analysis" mean, not only a method of test, but also a method of positive analysis and/or separation of physical, chemical and mechanical phenomena and/or properties, as follows:

1. Cracks, seams, flaws, non-metallic inclusions, segregations, external and internal defects.
2. Grain size, and characteristics of structure due to change in grain size.
3. Heat-treatment, hardness and decarbonization.
4. Comparative relation of all magnetic determinations as to Rockwell, Brinell and all microscopic studies.
5. Carbon contents in steel, comparison of a standard to a specimen as to physical and chemical properties, also the effect of a heat resisting element in an analysis indicated or recorded in terms of temperature.
6. Stresses and internal strains.
7. Separation of materials of equal volume but of varying chemical composition.

Discussion paper on "Automatic Arc Welding of Thin Sheets," * by Mr. W. L. Warner, General Electric Co.

Mr. A. M. Candy, Westinghouse Elec. & Mfg. Co.: Mr. Warner has certainly given us a lot of food for thought in this paper that he has just presented, but I would like to cover one or two details in connection with work of this sort.

In the first place, I would hate to have anyone leave the room this afternoon with the idea that these arc shifting difficulties, which we usually call arc blow, are entirely confined to the automatic arc welding process. In days gone by, before we had developed automatic arc welding machines, and before our welding engineers had been developed, the arc welding process, as a rule, was in the hands of the shop organization, and when the arc welder got into trouble, and produced poor welds, we blamed it onto his temperamental nature, without really investigating what was the trouble. Of course, in a great many cases, the troubles then from arc blow were not as pronounced as we found later, in the automatic arc welding, for a number of very good reasons. The magnitude of the arc difficulties varies considerably with the type of machine that is being used, and other details in connection with the design of the work being handled.

There are two questions that I would like to ask Mr. Warner. The first question is relative to the shifting of the plate edges as the weld progresses along the length of the seam. In hand welding, we have

*Paper to be published in December issue of the Journal of the A. W. S.

always found that as the weld was formed along the edges of the plates there was a very decided tendency for the plate edges to approach each other, and therefore, the technique of rigid and non-rigid welding was developed, the former being taken care of, as a rule, by tack welding, the tacked plates being held together in rigid alignment.

The other, non-rigid, was a cut and try method developed in the shop where the plates were placed at an angle with each other. In other words, the plates lay, in a common plane with the edges where the weld was to be commenced, rather closely together, possibly an eighth of an inch of separation. The far end of the seam would have separation up to an inch or more, according to the length of the seam.

Now, in automatic welding, the plates, instead of pulling together, have a tendency to separate. I would like to have Mr. Warner give us an explanation of that phenomenon.

Mr. Warner did not go into the question of welding galvanized sheet metal very extensively, and that is quite a problem before the industry at the present time. I would like to know what type of welding wire he has used in his experimental work, and whether or not he has worked with a non-ferrous wire for making these welds.

To get back onto the point I mentioned first, I want to again emphasize the fact that this arc blow, which is a difficulty that the operator gets into with the automatic process, is also encountered in hand welding, and we have noticed it very materially on structural welding work. Quite frequently customers who are not familiar with these phenomena in welding, blame the machine and blame the welding wire, and everything else except the design of the joint and location of the weld, and the direction in which the welding is done.

Those are features which need further study and development to determine the best technique for overcoming the difficulties.

A Member: In describing the length of the structure in the metal of the weld, Mr. Warner used the term Wiedmanstaaten. That structure is usually formed on slow cooling during the critical range. I wonder if welds cool very rapidly, and I am surprised it should be found in these structures.

Mr. Warner: I would like to say that, as far as any metallurgical explanation is concerned, I depend upon our metallurgist, G. R. Brophy; and, although I don't want to make him responsible for anything I may say in that connection, my understanding of it is that the Wiedmanstaaten structure occurred due to sudden cooling of the structure, which had been heated to the upper limit of the critical range, but not above. When it is carried over into the mushy condition and suddenly cooled, it is called "burned," and cannot be refined except by melting. If it is not heated above the dividing line and is cooled suddenly, we get the Wiedmanstaaten structure. That is my idea of it, but I cannot argue the case because I am not a metallurgist.

To answer Mr. Candy's two questions completely might take the rest of the afternoon, so I don't want to go into it too deeply. I don't profess to be able to answer them completely, either.

He speaks of hand welding where he used to do this. (Illustrating on the blackboard.) We used to leave the plates an eighth of an inch apart per foot of length and allow them to come together when welding. If we consider a piece of metal laid down at that point under the arc, as the arc progresses and the sheet is heated, that portion of the metal expands. It is heated more quickly than it cools, so that there is a tendency for the material to expand and stay partially expanded. If we could hold the heat long enough the material would probably come back to normal and there would not be any permanent effect. As you are welding in this direction (illustrating) you have an expansion in this direction, and in that direction, at right angles to the weld also. If expansion occurs in the direction of the weld it also must necessarily occur in three dimensions.

The net result is this (illustrating): In traveling at a high speed with the automatic, the separation of the plates is dependent upon the welding conditions, the speed at which you are traveling, the thickness and width of the plates. My theory is that if the plates are narrow enough so that their lateral stiffness is not sufficient to resist the bending stress caused by the longitudinal expansion of the strip of heated metal alongside of the joint, the effect is a separation of the plates. This effect is most noticeable on thin sheet with high welding speeds. If the width of the pieces is sufficient to resist this bending, then the lateral expansion and contraction come into play and cause the plates to come together. Whichever one of these effects takes place is, as was stated, dependent also on the welding conditions, the speed, heat, and thickness of material.

Now I cannot answer the second question completely. The wire that I have experimented with is our Type B wire. I have never tried the commercial fluxed wires, although we have experimented with bare wires.

I find that if you try to weld galvanized iron completely through the joint on a smooth, flat metal surface, you get porosity. If you watch behind the arc you can see the gas coming up. It comes up at just the right moment to be caught by the metal solidification. If you have a gap under the joint and don't weld through the sheet, or if you don't have a gap and don't weld through, the results are usually satisfactory. If you want to weld all the way through you must leave a space below the joint for the escape of the gases formed by the burning of the lower zinc coating. If you do this, of course, you have to take chances on the joint edges fitting closely and uniformly together. Suitable clamping is necessary in either case.

There is also the quality of steel to be considered, for the same troubles occur with galvanized iron as are encountered when welding sheet steel of unfavorable welding characteristics.

Mr. Henry Hobart, General Electric Co., Schenectady: While you have the chalk and blackboard handy, I wish you would explain to me about this opening and closing. Do you sometimes get one and then the other, according to speed and current?

Mr. Warner: On thin sheet metal strips we usually get the opening

effect. Where you have a cylindrical drum or box shape, the shape of the structure tends to stiffen the sides so that you don't get the opening effect. It is not necessary to tack a range boiler because of this stiffening effect, although it is sometimes done for convenience in handling.

Mr. Hobart: They still close sometimes as they used to?

Mr. Warner: Yes, sir, on the thick plates where the speed of welding is low. There must be a law of some sort governing this, but what it is I do not know.

Mr. Alva E. Taylor, American Rolling Mill Co.: I would like to ask Mr. Warner what is the minimum thickness of sheet that he has been able to weld satisfactorily with the electric arc process.

Mr. Warner: The minimum thickness of sheet which I have welded satisfactorily is No. 16 gage. I have seen No. 18 and No. 20 gage welded, and have known of these thicknesses being welded for ice cream cans at speeds of about 65 in. per minute. I have never seen this job and I don't know how the clamp operates, but I imagine the jaws are very close together. When welding this thin sheet it must be held tightly onto the backing bar or it will melt away from the arc like tissue paper before metal can be deposited from the electrode.

Mr. G. H. Koch, Westinghouse Elec. & Mfg. Co.: I would like to comment on Mr. Warner's discussion of arc blow in seam welds. He has described a machine for welding longitudinal seams in plates, or in tanks. Now, that is just one peculiar structure that we have to contend with. It is a structure that we come across pretty often, but there are also other types that we have to take into consideration.

Mr. Warner has shown one means of overcoming arc disturbance. At least, that part of the arc disturbance that is caused by magnetic field. There are other disturbances which assist the magnetic blow in making the arc weld.

It seems to me that on thin plates especially, and on all other work, if we can, we should try to eliminate arc disturbance by shunting out the field that is disturbing the arc, rather than by introducing a neutralizing means. Now, a neutralizing means is a very satisfactory way of balancing the arc. I have seen the thing in operation, but it leaves up to the operator the problem of adjusting for the neutralizing point which rapidly changes along the seam.

On thin plates, we have found no particular trouble in trying to quiet the arc to a point where we can get very satisfactory speeds. As a matter of fact, it very often happens when we start a new job, that we start welding, by picking out at random, a current value, wire and speed, that we arrive at from experience, and usually find a good deal of arc disturbance. Sometimes, without going into the matter any farther from the standpoint of magnetic blow elimination, we can obtain a very acceptable job by merely correlating the current value and speed and adjusting to the proper arc length for the electrode we are using.

We have often found in the laboratory that there is no arc blow to speak of in automatic arc welding of thin plates. There is some, of course, in every case, but there is none large enough to affect the results in a practical way. I am speaking here with reference to a definite case of welding plates about three-eighths of an inch thick and with about a 30 deg. V opening. By bringing these plates together so that they touch at the bottom, and using no backing at all, we have been able to obtain very high speeds with unfluxed wire.

Now, these machines have been built in various shapes, and a good deal of the blow that we experience in practical applications is introduced by the clamping machine that we use to hold our work.

Now, these machines have been built in various shapes, and a good deal of time has been expended in trying to change the disposition of the magnetic material around the seam, in order to shunt out the harmful effects of the disturbing field. I think this can be done very satisfactorily with thin plates in practically all cases without neutralizing means. With heavier plates, it is a different matter.

Mr. James W. Owens, Newport News Shipbuilding & Dry Dock Co.: Relative to the outward movement of the finishing end of a butt joint as welding progresses, I have found that this occurs in manual welding by both the gas and arc processes, also in automatic arc welding. What happens is that there is an advancing expanding area of the base metal adjacent to the point at which fusion is taking place, followed by a contracting area due to the cooling of the weld and adjacent base metal. The combined effect of these expanding and contracting areas causes the finishing end to move outward until the contracting force, exerted by the increasing length of the contracting area, is greater than the expanding force exerted by the expanding area. When this occurs, the plate edges on the finishing end will move toward each other and will sometimes actually shear the tack welds and the plates will overlap. I have found that in seams 4 ft. long, this outward movement of the finishing end will occur up to about one-half the length of the seam, after which the finishing end will start to come together. A curve showing this movement will be found on page 251 of my book, "Fundamentals of Welding."

Magnetic blow is a very annoying condition encountered in the practical application of automatic arc welding, particularly when the work is of a character which cannot be clamped in a machine provided with means to take care of it. In such cases, and when a butt weld is used, I have been able to overcome magnetic blow by manually reinforcing the weld on the underside prior to the automatic welding of the butt. The same can also be accomplished by the tacking of a light backing strip on the underside of the butt, the object in both cases being to close the magnetic circuit caused by the separated plate edges.

Mr. Warner has pointed out that this magnetic disturbance is greatest from $\frac{1}{8}$ to $\frac{1}{4}$ the length of the seam, therefore, if the seam is temporarily lengthened by the tacking of plates on the ends, it will be possible to weld the seam proper without serious magnetic disturbance. I have used this method with some degree of success.

Automatic welding can be applied to any thickness of metal, and I always use it in preference to manual welding, whenever it is possible to do so, regardless of the thickness of the material.

At the request of the A.S.M.E. Boiler Code Committee, the Society is submitting a Recommended Procedure for the Fusion Welding of Pressure Vessels. In going over this Recommended Procedure this morning with Mr. Obert, the chairman of the committee, I noticed that no provision was made for automatic welding. It is hoped, therefore, that this committee, of which I am a member, will not submit a recommended procedure to the Boiler Code Committee in which automatic welding is eliminated.

We have been told for years that welding cannot be generally approved for pressure vessels because of the human element, and now that various processes of automatic welding are available, it seems to me that its application should be welcomed by the Boiler Code Committee and that our committee should endeavor to induce the Boiler Code Committee to incorporate automatic welding in their Code for the Fusion Welding of Unfired Pressure Vessels.

R. W. Holt, Fusion Welding Corp.: I would like to make a drawing on the board of a method I used to quiet or neutralize the arc blow in welding.

I was welding experimentally, pieces of mild steel ⅜ in. x 3 in. x 22 in. long, and as the arc starts there is noted a blow in the direction of arrow No. 1, zone A, figure No. 1, as it enters and passes through zone B, a mild blow in the direction of arrow No. 2, getting stronger in zone C, as the arc approaches the end of the weld, where it shows a very strong tendency to travel in the reverse direction, as shown by arrow No. 3, zone C, figure No. 1.

It occurred to me, that the mass of the metal being welded, plus its shape, has a great deal to do with the direction of the magnetic blow. I took two pieces of mild steel ⅜ in. x 3 in. x 8 in., spaced them ½ in. apart, welding them not quite half their length, as shown by figure No. 2, leaving a half inch gap the rest of the way.

Here I have, so far as mass and shape are concerned, the substantial equivalent of figure No. 1, partially welded but turned end for end. I took this piece and placed it flat on the ends of the pieces being welded, as shown in figure No. 3. I found when the piece, figure No. 2, was placed, as shown in figure No. 3, it neutralized the magnetic blow, and if made heavy enough, would change the blow to the reverse direction, as shown by arrow 6, figure No. 3.

I could control the intensity of the effect of this piece in several different ways; one by changing the weight or thickness of the welded plates, figure No. 2, and another by changing their cross-section. I found it necessary to provide means for graduating the effect of the piece, figure No. 2, on the arc as the arc travels toward the end of the weld, as in zone C, figure No. 1.

I accomplished this by tapering the inside edges of the piece being used to neutralize the magnetic blow, as shown in figure No. 4. Figure

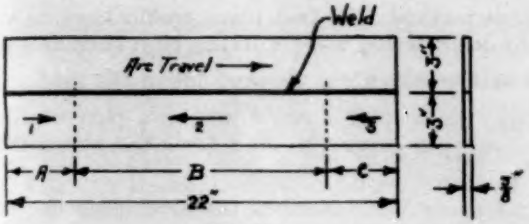

Fig I

Fig II

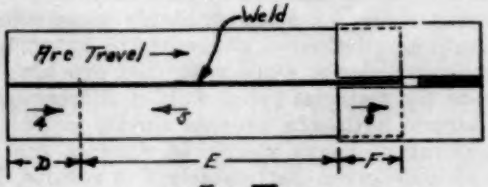

Fig III

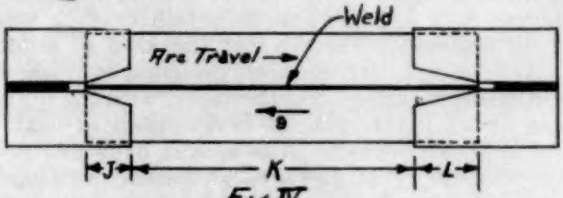

Fig IV

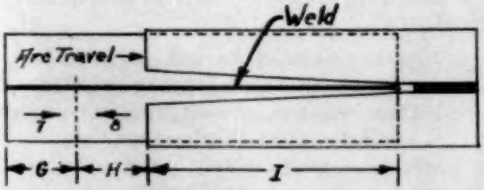

Fig V

No. 4 also shows another piece being used to neutralize the magnetic blow of the arc at the start of the weld (zone J).

Figure No. 5 shows how the piece for magnetic blow neutralization might be extended past the center of the pieces being welded so that this blow of the arc is controlled during the greater part of its travel.

By properly proportioning the weight, size, thickness and space as left by cutting away the inside edges of the piece (in some cases this will not be a straight taper), I could correct the magnetic blow in almost all instances.

Mr. Lunn: Did you try shifting the ground connection to get the same results?

Mr. Holt: Yes, but I could never correct it so thoroughly by ground

connection as I could by that method, and that piece would have to be incorporated with your hold-down if you were working on a certain job.

Mr. Lunn: It would be rather difficult to do that out in the field.

Mr. Holt: I don't see why those plates could not be a part of the top hold-down and continue on with copper, to hold down the plates the rest of the way.

Mr. H. M. Hobart: Mr. Warner has described the erratic nature of the behavior of the direct current welding arc, and has explained ways employed for overcoming the difficulties thereby occasioned in automatic welding. Others have explained the ways they employ or would suggest. Various among these ways are probably quite adequate. But the need for them would be eliminated altogether by automatic welding with the atomic hydrogen process, since with that process the current does not pass across to the material being welded. Moreover, I know of no reason why the atomic hydrogen process should not be applicable to the high speed welding of heavy pieces. In general, the atomic hydrogen process has already given particularly fine results, but its use should be extended upward to heavier material and to automatic welding at high speed, so as to obtain in such work the advantage of its good features. This is just the kind of work where the erratic behavior of the arc is most pronounced with ordinary direct current automatic welding. Furthermore, with the higher voltage of the hydrogen arc, a higher rate of development of heat is obtained for a given value of the current. The atomic hydrogen process is thus peculiarly appropriate for high-speed automatic welding of heavy material.

Chairman Adams: Isn't it a fact that these difficulties are not present with the alternating current arc?

Mr. Hobart: The tendency of the arc to be deflected ought to be decreased, but the current still crosses to the metal being welded. In general, although probably for other reasons, an alternating current arc has behaved erratically. I believe that high-speed automatic atomic arc welding of heavy parts is a particularly good proposition from every point of view. Welds, in general, are better when made quickly by the application of heat at a high rate.

Discussion paper, "Foreign Practice in Welding of Boiler Tubes and Drums,"* by G. Orrok.

Mr. Philip Swain read Mr. Orrok's paper.

C. W. Obert, Union Carbide & Carbon Research Laboratories: Mr. Orrok has given us a very interesting paper and he is to be commended for the data he has gathered and submitted. There are only one or two points in his paper that I think ought to be discussed: In the first paragraph of the paper, he starts out by saying that the Boiler Code in the United States forbids the use of welding, except hammer welding, in boiler construction. This gives a reflection on the situation which I don't think he intended. In the use of the

*Paper published in September, 1929, issue Journal of the A. W. S.

word "forbid," we generally have in mind a situation where something has been considered, weighed, tried out, and then turned down. That was not the case, however, in so far as welding is considered in the A.S.M.E. Boiler Code. In the sixteen years in which the A.S.M.E. Boiler Code has been operative, the absence of rules for fusion welding in the Boiler Code is due to the inability of the welding industry to tell the Boiler Code Committee how to formulate those rules, and not to any purpose of the committee to restrict or prohibit. What Mr. Orrok probably should have said, is "The Boiler Code Committee has not provided for the use of welding," which is true. It hasn't reached that point as yet, although they are undoubtedly very close to it at this time.

When Mr. Orrok spoke in the fourth paragraph of his paper about the shells of low-pressure boilers, I don't think he meant low pressure in the sense that it is used in the Low-Pressure Heating Boiler Code. In the Code parlance, a low-pressure boiler is one that operates at 15 lb. pressure or less. Everything above that pressure is treated as high pressure.

Inasmuch as he refers to the Cornish and Lancashire types, I think he has reference to relatively low-pressure boilers, perhaps 125 lb. and less, because it is a fact that over in Europe, boilers of that type have been welded; in fact, boilers have been welded for pressures up to 1500 and 3200 lb. working pressure in types that avoid the use of drums.

The Garbe type of boiler is a German boiler which is the equivalent of several of our vertical water tube types, in which the tubes are straight and enter the exterior of the shell without bending. The Garbe shell is pressed so that each tube seat is directed at right angles to the axis of the tube. That has, as far as I can learn by reading the foreign papers, been accomplished without great difficulty by pressing or bumping one-half of the shell before the other half of the cylinder is welded to it.

The author speaks of the adherence to hammer welding by the three larger firms making this type of product. That is true. At the present time with the lack of recognition of fusion welding in the A.S.M.E. Boiler Code, it is, of course, impractical to operate a welded drum in the states in which the Code is effective. It is possible, however, that the practice may be inaugurated in this country by users of boilers in a non-code state, in order to try the thing out generally; in fact, information has come to my attention quite recently that such a project is under consideration.

In the second paragraph on Page 111, Mr. Orrok states that "welded boiler drums with forged ends are quite common." I understand that to mean hammer-welded drums. I don't understand that fusion-welded drums have been welded up and end-forged. If so, I wish to be corrected. I hope the secretary will bring that point to Mr. Orrok's attention, and give us correct information on it.

On Page 112, he states: "The test above the elastic limit with subsequent annealing has made it easy for the designer to cut down the

factors of ignorance of the older school of boiler construction." This is one method of checking up on both design and construction work that has had great attraction for many designers. It has been suggested that the practice of welding the boiler drum and then stretching it with the hydrostatic test beyond yield point, has great advantages. If it stands that test, it should be permitted, perhaps with subsequent annealing. In fact, a number of boiler designers have come before the Boiler Code Committee and pointed this method out as a possible practical means of approaching this problem. Unfortunately, however, nobody has tried it out on a large scale in this country. This involves exactly the same practice that is used by certain compressed gas companies in forming their shipping cylinders; that is after their cylinders are drawn and formed they are put under a stress that will stretch them beyond the elastic limit, in order to determine their strength and soundness.

I am very glad to note what Mr. Orrok has said in his paper about research on boiler design problems, including tests of full-sized structures. At this rather critical stage of the development of the steam boiler in this country, that offers the greatest opportunity for developing along the line of either fusion welding, hammer welding or seamless forged drum construction. It is the lack of such research information that is hampering the development of the welding; if it is going to remain for a few of the large concerns to develop that knowledge by their own research, progress is going to be decidedly slow, much slower than that which Mr. Orrok is reporting on in Europe. The European boiler concerns are apparently jumping by leaps and bounds ahead of what we are accomplishing in this country.

When Mr. Orrok states that the two objections to welded joints most commonly heard in the last few years, the lack of resiliency and the welder's skill factor, are heard less and less, he is, of course, stating facts. In the earliest stages of welding, the inspector out in the field, the insurance man, would invariably bring up those two points, and state that the weld is just cast iron; if a little pressure is put on it, it cracks, further, the irresponsible welder can throw in the metal and build over the holes and how do we know what is inside? It does seem that the industry has advanced beyond that stage, and we have now got to the point where any number of reputable concerns can put up a welded structure without any question of that sort.

On page 113, the author touches on the embrittlement problem. It is the loss of boiler drums by caustic embrittlement which is occurring at an increasingly rapid rate, apparently, that is stirring up the boiler industry toward welded drum construction at the present time, particularly as we approach the very high pressures. It is well known to those of you who have contact with the boiler field, that the industry is working rapidly toward six hundred, nine hundred and twelve hundred pounds operating pressures. As these pressures go up, the difficulties in embrittlement, and consequent cracking, become an overpowering difficulty. It has got to the point where a large power plant operating concern hesitates to use a riveted drum as they work up to the high pressures.

Every year we think that improved operating methods have eradicated that thing, but operators are losing boilers at an increasingly rapid rate. It isn't at all uncommon for an insurance inspector to go into a big power plant, perhaps only two or three years old, and find cracks in the joints or rivet heads flying off, so that he may shut down the whole plant. It isn't at all surprising that these operators should come forward and say, "Why can't we use welded drums?" When they consider the forge welded drum they find there is a practical limit of something around 1½ in. or 2 in., which leaves the field open only to fusion welding, or seamless forged construction. The seamless forged drum is exceedingly expensive, and it therefore places the opportunity squarely before the fusion-welding industry to work it out on some basis.

Mr. Orrok points out one factor that is going to be very pertinent when we do have welded drums. Speaking of the factor of safety, he says: "However large may be the average factor of safety in boiler parts, accidents will happen in cases of gradually developed local weaknesses. . . ." It wouldn't be at all surprising if after we start in using fusion-welded boiler drums, there were to be a failure which would cause damage, it would be said: "You should not use welding." But I don't think the boiler industry is in that state of mind at this stage. I think the state inspectors and insurance companies are becoming educated to such an extent that they recognize this possibility and are prepared to face that question fairly and squarely. If, perhaps, we do have an accident with a welded drum, I think they will be prepared to treat it in the same light as they would treat a similar failure of a forge welded or a riveted drum, cases of which are, of course, not unknown.

Mr. Orrok closes his paper with these remarks: "It would appear that our boiler codes need modification in such fashion as to allow the use of the three later forms of welding under proper safeguards." That is a very pertinent suggestion, but no one should assume from that remark that the Boiler Code Committee has been asleep to it. The entire problem of codifying welded construction has been one of the most active subjects the committee has had to consider all through these years. The fact that it has been giving careful consideration to the problem is well known to the officers of your organization.

There is now, as most of you know, a cooperative relationship between the Boiler Code Committee and the American Welding Society. There has been a Pressure Vessel Committee of the Welding Society in existence for many years, but last year a renewed arrangement for this cooperation was made by the appointment of a committee by our Society to confer with the Boiler Code Committee on these big problems. The responsibility for putting a set of rules into the Boiler Code that will adequately provide for fusion welding is no small task, but the Boiler Code Committee is far-sighted enough to be willing to share the responsibility, and it has insisted that the American Welding Society come in on the problem. The assistance it is receiving from the American Welding Society is much appreciated.

If you are interested in the latest development in the Code, the revisions of the Unfired Pressure Vessel Code which are under way, may be mentioned. As you all know, the present Unfired Pressure Vessel Code limits the diameter of fusion-welded vessels to 20 in., the pressure to 100 lb. and working stress of the joints at 5600 lb., in cases where the entire vessel is welded, including the longitudinal seam. If, however, the longitudinal seam is fabricated in some other manner, and only girth seams are considered, such vessels can be welded in the girth seams up to 48 in. except where vessels have through tubes or braces from end to end, which vessels can be welded up to 72 in.

This whole group of rules is being changed by revision which is based on the Recommended Procedure that the Welding Society formulated last year and placed in the hands of the Boiler Code Committee about the first of this year. The revised rules will provide that all welded vessels may be fabricated up to 60 in. diameter, to working pressure of 200 lb., and for a working stress on the joint that varies with the class of the joint, but has its highest stress for butt-welded joints which are allowed 8000 lb. It is arranged, to be exact, in the same range of stresses that was imposed in the State of California, when it adopted its unfired vessel code the first of last year.

It should be understood that these revisions, when made effective, are applicable only in case that the particular Recommended Procedure is followed. If that isn't followed, the former narrow limits still apply.

But, of course, this set of revisions does not complete the story. Many are going to say: "Why do we want any limitations on a welded vessel?" That is a very pertinent question. It is only perhaps a continuation of the old uncertainty or doubt about the welded joint that holds the committee back from removing the limits entirely and basing the revision on a stress allowance rather than on the Procedure or some other particular feature of the weld.

As I see it, the most hopeful opportunity for eliminating all of the uncertainty about welds, will be the development of some method of non-destructive tests of welded joints, either of the Sperry method, the magnetic method, or possibly the X-ray in combination with stethoscope. If something like that proves itself effective it will undoubtedly be the most practical thing for the Boiler Code Committee to consider.

If that is not accomplished, it is hard to say just what will be needed, but certainly we can agree that something is needed, beyond a mere procedure. Perhaps years of experience and practice and knowledge of what will be obtained in welded joints is the answer. At any rate, something more critical than a procedure is necessary to be attained before the committee can take that final step, because it is a step of great importance and places a great responsibility on the Society or body that does take the step.

Mr. James W. Owens: I would be the last one to hold up the progress now being made by the Boiler Code Committee, but as automatic welding overcomes many of the objections which have been raised in the past as to manual welding, I cannot see why there should be any

hesitation of the Boiler Code Committee to accept it if it is incorporated in our Recommended Procedure. In this Procedure, we require certain tests for the qualification of welders. In like manner, a test could and should be required for the acceptance of a machine-welding process. This test should be required for the various thicknesses of material to be welded and, if necessary, one or more tests for each series of pressure vessels manufactured. I do not think it would be necessary to radically change the Procedure as at present drafted for manual welding, for all that is necessary, would be to introduce a clause to the effect that welds made by the automatic process shall show the minimum requirements specified for manual welding. If this is done, there should be no delay in the submission of our Procedure and its adoption by the Boiler Code Committee.

Chairman Adams: I wonder if we can hear from Mr. Fish?

Mr. Fish: There isn't anything much left for me to say after Mr. Obert's discussion of the whole question. I, of course, am primarily interested in steam-pressure containers, or the boiler end of it. A boiler has tremendous destructive potentialities. It is an instrument capable of very great disastrous consequences if a major accident happens to it, and for that reason alone, it is quite right that the permission to use welding in the construction of containers of that sort has been delayed.

The way in which the work should be done, the kind of welding that should be used, is up to the Welding Society to dictate. I think the "procedure control" came from the Welding Society primarily; it was not initiated by the Boiler Code Committee, which looks to the Welding Society and those who are experts for advice.

If the automatic welding method should be included, it is for the Welding people to tell us so and how and not for the Boiler Code Committee to try to include it.

As Mr. Obert pointed out, the time is now imminent when welding will be permitted, will be recognized rather, by the Code and quite justly so. There are a good many of us who would have been willing some time ago to have recognized and permitted it, but there are other interests who have been very much opposed to it. The rule has been not to make any rulings that are not unanimous. We don't go by the majority rule; we go by the unanimous rule, so in that way we perhaps play rather too safe in the eyes of some, but it is erring on the safe side; the code is a safety code. That is the primary reason for it.

The European countries, I think, have done and used welding to a very much greater extent than we have over here, in some of these important structures. I remember a good many years ago, they were using welding in boilers, and they had some bad failures, so that we were glad we didn't take it up, and I think quite rightly so.

You have progressed in your methods in the technique of making welds, and the very fact that the authorities have not permitted the use of welding in pressure vessels has unquestionably tended to keep

you on your toes, and make the art progress perhaps faster than it would have, so that by being a little super-cautious and a little slow, the Boiler Code Committee has caused the art to go forward a little faster and a little better than it perhaps would have otherwise.

Chairman Adams: I want to support what Mr. Fish has said, and also what Mr. Obert has said. I am a member of the A.S.M.E. welding subcommittee of the Boiler Code Committee, and although my primary interest has been on the welding side, I have always been glad that the Boiler Code Committee was so extremely conservative. I think they are right when they say that it is up to us to prepare either some kind of a procedure control which will insure high quality work, or some specification for tests which will insure that same quality of work. Unfortunately, in the past, we haven't had the test methods which would cover the ground with sufficient thoroughness to satisfy everybody and from the papers we have had today, it is pretty evident that we are going to have those test methods in the near future. I feel sure that some test procedure, test specifications, will be provided (and that in the very near future), which will be sufficient without detailed specifications as to just how the work is to be done.

The real specifications for any piece of apparatus are statements as to what that apparatus shall accomplish and not how it shall be made. We are going to get those specifications in the very near future.

Paul Orr, Westinghouse Electric & Manufacturing Company: I have enjoyed the different talks this afternoon very much on the procedure control of welding, but I just wonder if we some time would have a meeting and discuss the human element part of good welding; what we have been trying to do this afternoon is to eliminate this human element. Is it not possible that we can control it and do better welding?

I think there are some gentlemen here who will bear me out in this statement, that if I know the men who are doing the work, I can guarantee welding. Would it not be possible to control this human element which in turn will help us farther along with welding, than what we have been getting in the past few years? I would like to hear from some of the gentlemen here on this subject.

Mr. K. MacPherson, Atmington Engineering Co.: I am a welding operator and believe that I am different from the usual run of gas and arc welders found in the majority of factories today.

The reason you find this other type of operator, is because the Society is not training and placing the right kind of a man in the welders' profession. In other words, it has been the custom to train a man who is capable of doing manual labor, giving little consideration to his mental capacity.

Now, if we can get a better type of man interested in welding, we could train and educate him, not only to manipulate the arc but to understand the effects and fundamental principle of welding.

He does not have to be a college man or engineer, but should have a basic knowledge of the art and science of welding.

So, I believe if this phase of the question was taken up and carried out, it would advance the welding standards and result in the acceptance by industry to a greater extent than heretofore has been the custom.

Chairman Adams: I would like to call the attention of the last speaker to the fact that the Welding Society provides a class of membership for operators. We have done everything that we can do to hold the attention and interest of that group of men, and if we had more of the type of the last speaker in the Society, we would all be better off and very glad of it.

It has been a very interesting meeting, and this last paper touches on a very big field. I am sure the Boiler Code Committee is just as anxious as any of us to make progress in this work, and I feel sure that they are going to make progress just as rapidly as we are able to back them up.

Mr. Fish: I just want to suggest, Mr. Chairman, that if there are any here who have any ideas as to what the procedure control should be, what provisions should be put into such a draft, that they make it their business to get into contact with your committee and get their ideas to them.

It is hard to get ideas from anybody at any time, and when a committee sits down and tries to do something themselves, there are likely to be those who afterwards complain, but who, if they had previously given the matter attention, might have had their ideas embodied also, so that when the rules are put out, it is their own fault if the rules don't meet with their approval.

The chance to comment on them will be given and if anyone fails to take advantage of that opportunity, it is his own fault and not the fault of the committee that draws up the recommendations.

FRIDAY MORNING

September 13, 1929

J. C. LINCOLN, Presiding

Chairman Lincoln: We have this morning for presentation three papers. The first paper is by Mr. W. R. Ost, of the Air Reduction Sales Company, which covers the "Oxy-Acetylene Welding of Pipe Lines in the Field."*

The second paper is a paper** by Mr. H. C. Price, covering the same subject by the electric arc process. If there is no objection on the part of the audience, I am going to ask that the first two papers be presented together, Mr. Ost presenting his paper first, and Mr. Price, his paper second, and that the discussion be started after the two papers have been presented.

*Paper published in September, 1929, issue Journal of the A. W. S.
**Published in the October issue of the Journal.

. . . Mr. Ost presented his paper entitled, "Oxy-Acetylene Welding of Pipe Lines in the Field." . . . (Applause.)

Chairman Lincoln: I think we are greatly indebted to Mr. Ost for the cost information which he gives in the paper. Eventually, most all processes have to meet this cost situation. I suppose that in some cases Bessemer steel is used now rather than open-hearth steel because the cost is lower, and I say again we are greatly indebted to Mr. Ost in giving the costs in pipe-line welding.

The next paper will be presented by Mr. Price, and Mr. Price's paper covers the electric welding of a pipe line, and I have great pleasure in introducing to you Mr. H. C. Price, of the Welding Engineering Company, who will give this paper.

. . . Mr. Price gave his prepared paper. . . . (Applause.)

Chairman Lincoln: These two most valuable papers on a subject which is comparatively new are now open for discussion.

President Llewellyn: Mr. Price stated that the tests on these pipe lines were made as soon as possible after the completion of each portion of the work. I have understood from metallurgists engaged in the testing of steel that you get very different results if you test steel the day it is rolled or immediately thereafter from what you get if you wait several days, and I have been wondering whether in the case of welded pipe different results would be obtained if the tests were made immediately; from what would be obtained if they were made after the lapse of twenty-four or thirty-six hours.

Mr. Price: The truth is that most of the lines are tested after that lapse of time. It takes that long for them to get the water in the line. However, that brings up the point as to how the lines are after they have been there a year or so. As I say, the first line was welded only a year ago. That line was from St. Augustine to Corsicana, Tex. The last information we had of it, they had no leaks or seeps or anything of that sort, and that line passed through the past winter and the floods of this spring.

Mr. Glenn Owen Carter, Linde Air Products Co., New York: I was asked to comment on these papers and I might as well start the ball rolling. Probably the reason I was asked to comment on these papers is that I have followed this pipe-line welding since 1921 or 1922, when it was first introduced.

The points that have been made by both these gentlemen in the management of the lines are very well taken. In the development of the welded pipe lines we have gone from the use of teams to the use of mechanical equipment. I well recall that on the first Magnolia line put in about six or seven years ago, everything was done with teams, mules. The result of some of that work was excellent; we did use a few things that were commented on in Mr. Ost's paper, such as the feeder lines to supply acetylene in large quantities along the right of way, but we only made a few of the steps that have been made since then.

Standard power equipment is used now instead of the mule. Almost never do we see anything but the caterpillar; not only that, but the caterpillar that has the crane that will pick up the pipe and put it in position. Many of these lines no longer have a "bull gang," as the line-up gang is called.

I am bringing out this point to make another point, that is, that the question of cost, efficiencies, are changing every year. It is primarily a matter of management of the whole project, and it is the overall cost that we are all pointing to. It is extremely difficult to take the cost of six or seven years ago, compared with the line laid last year, possibly in fair weather, so we have to begin to get this information whipped into shape and presented as we are presenting it here in open discussion, and establishing our standards.

There is another angle to this, and that is the question of quality. I note the comment made about the high-grade filler by Mr. Ost. Also mention by Mr. Price that their cost of electric wire is very much lower than the cost of acetylene welding wire. It has been our effort to keep the practice in the industry along the highest level. Mr. Price mentioned a strength of joint of 75 per cent for electric welding whereas in the lengthy series of tests conducted in the past two years, acetylene welded joints ran 92 per cent of the total over the average, and 80 per cent of these were right up within 95 per cent of the pull of the pipe itself.

Last year at the Acetylene Convention, we were told by one man that we were aiming too high; that none of the other types of joint in use would anywhere near outpull pipe; that we were penalizing ourselves by aiming at 100 per cent. Possibly, that is true; I leave that for your consideration. We have been aiming at that partly for this reason: If you can afford to get by with a 70 per cent joint, why not produce a 100 per cent joint and reduce the weight of the pipe? That is our objective.

Now, the failure of welds has a psychological effect. A stress has been put on the pipe that would disrupt it and the weld fails. I had the pleasure of standing last week and witnessing some tests that ran over 85,000 lb. per sq. in., which, however, failed in the weld, and although the above strength was reached, yet there was a feeling that the failure was in the weld. It pays us to try to keep the weld above the strength of the material we are working on.

There is quite a question in the matter of bonus payments, which involves the expense of very careful inspection. I am glad to note that they are using the slotting machine. That is another thing we had the pleasure of introducing into the art. It is a very effective means of cutting a slice out of the weld, and knowing approximately where it stands. Incidentally, it can be used to cut out tensile specimens if you want to. I believe the American Welding Society is opposed to bonus methods. Unquestionably the bonus methods have an important effect upon costs provided they are carrying inspection so thoroughly that you get a good job. I am not making any reflections upon Mr. Price because I know his management has been exceptional.

Mr. Ost made some points about the use of larger heads for welding than have been called for by the tables. We quite agree on that, except for this, that when you get into the higher carbon materials, it seems to be advantageous to use as small a flame as will give good welding. The characteristics of the higher carbon are a little different from the lower carbon. The actual cost of welding does not vary a great deal when you have the men well trained, however.

I add that, as a caution that I hope will go in the record because we have found that too big a flame on some of the higher strength pipes gives results that are poor in a physical, not chemical way. Many of the men find that there is trouble and blame it on the rod. The fact of the matter is that they carry too large a flame, and when cooling down suddenly as they take the flame off, they have trouble.

Of course, we agree on the high-grade rods. That is one of the things that was initiated years ago by S. W. Miller, and I think we have all been in accord throughout the Society ever since.

I believe in establishing the standards and holding to them: At the beginning of any job it would be well for the engineers who intend to follow the inspection; the management responsible for the costs and the agents of the supply organization, if they are working with these people, to get together on what is going to be a standard for the job, and then try to hold the inspection methods so they will get the results they are looking for. If you don't set such standards, there are many questions that will crop up. The production man will try to push the job through too fast and will fall below what he ought to. On the other hand, if the material man sets his standards too high, it makes it difficult for the production man to go ahead.

One statement made about the comparison of costs between oxy-acetylene and electric welding, left out the cost of formation of the bell and spigot joint. To the best of my knowledge, what electrical welding has been done has been practically all on the bell and spigot. There is the belling cost. Somebody pays it. I have been told that it is somewhere around $5 a ton. That forming cost must be taken into consideration.

Second, you have the additional metal to be paid for outside the forming cost. I think that will have an important bearing upon what your line will cost for 250 miles or so.

Again, the welding dam: the forming cost of that must be considered. It cannot be done for nothing.

In regard to the testing of the lines—the oxy-acetylene lines have had a history since 1921 or 1922 of practically no failures on any line below 12 in. in diameter. It is almost an unheard-of thing to have a failure at any time after the line is put in. One line of 280 miles in length from Chicago to Wood River, in the general direction of St. Louis, had one split in the longitudinal seam, and not a failure in the welds of any nature.

As I said at the beginning of this comment, unquestionably we are facing the study of the management of the project so you will get an

overall cost that will make the work satisfactory. In some of the work that has gone on this year, mention was made of 2500 miles of one form of welding. Last year there were 5000 miles of oxy-acetylene welding, and this year much more and lots of it has been over mountains and over a very rough country, and I understand we are still very much "in the ring," in the eyes of those who have been following welding in those sections.

Mr. Price: I have made some notes of what Mr. Carter said, and will try to give him an answer. As to the bonus—we have been electric welding contractors since 1921, and we have found that the bonus has never hurt us at any time. Our company has welded over four hundred tank roofs of large oil tanks without a failure.

As to the inspection on these lines, I am certain that the inspection would be just as severe if we worked on straight time as on bonus. I am positive of it. There is no reason that I can see why it should not be because I don't think an electric welder will do any better or any poorer work on a pipe line or a tank roof on bonus than he will on straight time.

Another point about the bonus on pipe lines. I think it is an important one. We have used stop watches on men that made twelve welds a day, and men that made twenty, and on the actual time of welding a joint there is only a few seconds difference. The time lost is between welds, and that is what we are paying the bonus for, to make them work between welds. You take a man that makes a high day's run, you will find that he is running between welds, and if you were not paying a bonus, you would find that he was smoking between welds.

As to the cost for the pipe joint, Mr. Carter is right. I have known bell and spigot pipe with a welding dam to be quoted from the mills at a considerable increase over plain end, but again I have known this type of joint to be bought at only a small increase, and some time at no increase in price over the plain end. It is a question of when and where it is purchased, and is a matter for the purchasing department to thrash out.

As to the cost of the extra length of pipe: I presume Mr. Carter means where the loss is two and a half or three inches because of the overlap of the bell. That is a loss, but it is overcome immediately by the fact that you do not need a tacking machine. That alone will pay for that extra length of pipe, and I still feel sure that if you do have to pay something extra for the bell and spigot joint, it will more than be made up in the welding.

President Llewellyn: If I may rise again, I would like to speak of the impression left, I think, by Mr. Carter, that the American Welding Society was opposed to the use of bonuses. As an officer of the Society, I am not familiar with any such attitude on the part of the American Welding Society. The question has come before the officers of the Society, before the Executive Committee, before the Board of Directors, to my knowledge twice within the last year, and at that

time it was the sense of both of these bodies, as well as of all the individual members with whom I have discussed it, that this question was outside of our province, that it was the function of the American Welding Society to outline requirements, but not to pass upon commercial methods. It was recognized there might be certain places where piecework, including bonuses, would be undesirable, and other places where bonuses would be desirable, but that the determination of this matter lay with the contractor doing the work, and was not the affair of the American Welding Society.

Mr. Davis: I would like to ask Mr. Price if he found any difference in the tensile strength of the weld in the plain bell and spigot and the bell and spigot of the welding line.

Mr. Price: I don't know; in fact, on the 8-in. line no tensile strength tests were made, and that is the only line on which we had the bell and spigot and the welding dam.

Mr. A. M. Candy: Mr. Chairman, I don't know anything about pipeline welding so, therefore, I feel qualified to ask a few questions.

The two papers delivered by Mr. Ost and Mr. Price have certainly given us a great deal to think about. Mr. Ost particularly sounded a keynote when he first started to speak, which I think should be emphasized again at this meeting, especially in view of some things that have transpired, and have been brought up at some of our committee meetings.

The item that I refer to is a statement by him as I understood it, to the effect that the question of the strength of pipe lines, and their integrity was now second to the question of cost. In other words, confidence has been established throughout the industry in the use of welded lines. Personally, I feel that this same confidence has been established in all other welding undertakings, such as the manufacture of machinery, and tanks in general, and a great deal of welding work which is going on today. As a matter of fact, my experience during the past year in having various visitors come to our factory at East Pittsburgh, has been that inquiry has always been as to the cost of the operation, how it is done, and very seldom has the question of the integrity of the welded structure been brought up. We have had discussions in our meetings about poor welds and welds that showed lack of fusion and tests in general that showed up poorly and that may have scared out some individuals who have attended these meetings, but if they will go around through the various plants in the country doing welding, I think their confidence will be established by the fact that thousands of tons of steel are being welded each year by plants in this country.

Now, to raise a few questions on some of the details: In Mr. Ost's paper, it would be interesting for some of us to know at least how large the tack welds are required for lining up the lengths of pipe before starting the firing-line operation, and at what intervals those tack welds are located around the pipe.

Mr. Price, in his paper, mentioned the river crossings, and I didn't

quite get the point about the second line placed up stream, or down stream, as the case may be. Is that a reserve line that is to be used in case of failure of the original or just what is the object?

Another question, which I thought of in connection with Mr. Price's paper is the question of determining the leakage in the line. He mentioned a rather startlingly low number of leaks were found and also mentioned that there were undoubtedly other leaks that were not found. The question would naturally pop into my mind, How are these leaks determined? We have had a considerable amount of experience in our work at the factory in locating leaks, especially in building tanks which must withstand or hold a vacuum for an appreciable length of time without any perceptible decrease in the vacuum.

Mr. Carter in his discussion of these papers, raised a point of the much higher efficiency of the oxy-acetylene joint compared with the welded joint, and suggested in as much as that efficiency was on a ratio of 90 to 70 per cent, therefore, we should reduce the thickness of our pipe by that amount, which would be about 22 per cent, and take advantage of the higher strength. I am wondering what Mr. Speller and some other gentlemen who have had considerable experience on corrosion would think of such a proposal in actual practice.

One other point that was brought out by Mr. Carter relative to the difference in cost of the line, by the amount of metal required in the bell and spigot joint, and by the expense of forming the bell and forming the dam: I am not real sure that the dam is necessary. However, I think that point was partially answered by Mr. Price in stating that with that type of joint, no tacking was required, and it also struck me that theoretically, at least—practically, this may not be true—it looks to me that the lining up of bell and spigot line would be cheaper than the lining up of butt-welded joints, even with the slick little clamp we saw on the screen which is an ingenious little device.

W. R. Ost, Air Reduction Sales Company: The question of tacking pipe lines has been settled as far as gas people are concerned. The American Gas Association has specified a definite number of tacks: two, three or four tacks around the pipe for each diameter of pipe when a certain number of lengths are joined into a section. Those specifications are not always followed, particularly on jobs that are carried on in the following manner. The first welder welds two lengths of pipe together, into sections of twos, another welder follows along and welds these into sections of fours, etc. No tacking is used here. Generally when a section of pipe containing two or more lengths has to be turned or rolled, a minimum of three and possibly four tacks are used at each joint.

Our company has had the opportunity during this past year to work with bell and spigot pipe. They cooperated in laying between 150 and 200 miles of bell and spigot pipe, with gas-welded joints. This work was carried on without tacking. It was a case where the company could buy bell and spigot at the same price as butt-end veed pipe, but they found later that they were adding thirty cents to the cost of each joint even though the cost per ton for each pipe was the same.

When we have welded bell and spigot pipe without tacking the cost per joint has not been any cheaper than when welding plain veed butt-end pipe. As a matter of fact, the speed was a little slower when welding the bell and spigot pipe.

I have also been favored to see a comparison between electric and gas welding mile per mile, identically the same, on bell and spigot pipe. The comparison showed that gas welding was cheaper by 25 per cent.

There seems to be a difference in pipe-joint costs, between Mr. Price and myself. But it is a point well taken, to know what items should be included to determine the cost. I believe there is a difference in tabulation of the general cost items.

Contractors we have been working with usually figure the cost of a pipe line, on a footage basis. The cost per joint usually means only the welding operations.

Leakage is another big factor in pipe-line work. Leakage of oil lines in the country and leakage of natural gas lines in the city areas have been the cause of many damage suits.

The Bureau of Mines has given us a very fine paper on the leakage rate of natural gas transmission lines and also on the leakage rate of various sized holes. If my memory is correct, a 1/16-in. hole in a pipe carrying 300 lb. gas pressure, would leak nearly seven million cu. ft. per year.

I mentioned leakage because it serves to illustrate a point regarding the cost of joints. A leaking joint is expensive no matter how cheap its first cost is.

Mr. Price: In answering Mr. Candy about the two river lines, the second line is put in for an emergency. Should anything happen to a line laid in either the Mississippi or the Missouri Rivers, why, it would be very disastrous if they did not have another line to pump through.

As to the determination of leaks, the first thing they do is watch the pressure, and if it drops more than 10 lb. (I think I am correct in this) in twenty-four hours, then they look for trouble. At the same time, they also watch the line. But I don't want to give the wrong impression. This pipe is covered. A lot of it is in the ditch and minor leaks probably would not be found; that is, if they would only cause up to a 10-lb. drop in twenty-four hours. There might be a very fine seep in the ground which might not be found. It would probably take up itself.

I am glad that Mr. Candy brought up the point about lining up pipe. It is much easier to line up pipe with the bell and spigot joint than with the plain butt joint, and there is considerable saving in cost of labor.

Chairman Lincoln: It happens that we have with us Mr. Speller, an authority on corrosion. We would like to hear from him.

F. N. Speller, National Tube Company: The question of which sys-

tem of welding is most suitable and economical for connecting pipe in the field is not one in which the manufacturers of pipe are particularly interested, except in a general way. The methods that are found most suitable for mill use are not necessarily the best for the field.

As to the influence of wall thickness on corrosion, it would seem that the thickness is more closely connected with the factor of safety and is a question for pipe-line engineers to settle. There may be quite a number of pit holes almost through the wall of the pipe without affecting the ultimate strength of the pipe under pressure. The question of corrosion, of course, is not the only factor to be considered in deciding the thickness of pipe. If the pipe line happens to run through a corrosive soil, a difference of 20 per cent in thickness is of some consideration, but it then becomes a question of applying suitable protective coatings, and with such a coating applied a difference of 20 per cent in thickness of the wall is probably not a factor in the life of the pipe. The probability is that in the ordinary course of events the pipe line would be reconditioned and recoated before corrosion has a chance to extend more than half way through the pipe.

Chairman Lincoln: Any further discussion on these two papers?

Charles S. Dresher, Greenwich Gas Company, Greenwich, Conn.: I wish to compliment the two speakers on the excellent papers they have submitted. Although I am more interested in the acetylene process, I was extremely interested in Mr. Price's able paper. I certainly couldn't quite understand why the welding wire in the welded electric joint should be 22 per cent less than in the acetylene, although I admit the average acetylene welder will make a joint altogether out of proportion. I know many of the welders I have seen, instead of adhering to the formula that Mr. Ost gave of the approximate 25 per cent reinforcement, will probably go up to 125 unless you reduce them a little. Just where Mr. Ost got 10 cent welding wire, I don't know. At any rate, I can't see ten cent wire on the price list today, particularly when he speaks of high-test wire.

The A. G. A. last year did a good deal of investigation work on the strength of joints, and the high test wire certainly gave extremely favorable results, details of which are given in Report of Subcommittee on Pipe Joints, submitted to the 1928 convention. Mr. Henderson, the engineer of the Los Angeles Gas & Electric Co., submitted quite a number of figures on acetylene welds that I believe would make even Mr. Price's electric weld look extremely expensive, but that is in Los Angeles where, after all, they are paying wages that would probably cause us difficulties, so I don't think the Los Angeles cost factors are of much value to use here. But I have certainly enjoyed the discussion, and I hope that when Mr. Ost has some ten-cent high test wire available, he will let me know. (Applause)

Mr. T. W. Greene: I have been very much interested in the discussion this morning, both in regard to oxy-acetylene welding and electric welding of pipe lines. One factor has been mentioned that has a rather important bearing both on the quality of welding and the economics of pipe line construction, and that is tacking, it being stated that tacking

can be eliminated and saving effected through the use of the bell and spigot joint. Tacking serves two functions, outside of welding requirement of spacing for a butt weld, that is applicable to all joints in the field. It maintains alignment so that aligned pipe can be handled and rotated, and also keeps the aligned pipe in assembly, preventing the individual lengths from separation, expansion and contraction. Variations in temperature during the day and night will tend to pull the assembled joint apart, particularly if the pipe sections are aligned several days ahead of the welding operation. I have noticed in several electric welded installations, that the bell and spigot joint is tacked, although the deposited metal may serve as part of the first bead of the weld. This does, however, require an extra machine, with tractor or motive power, as it is continually moving and must keep up with the line-up gang. For the tie-in welds, tacking is essential, for the assembled sections of welded lengths must be held while the pipe is being bent or snaked for slack, since it would be costly to hold up the tie-in crew until a field weld is completed. All this requires additional equipment.

There have been several installations where, through coordination of various crews, tacking has been eliminated with gas welding, and the same could hold true of electric welding. In this case, the pipe is aligned by the line-up crew and not tacked, and the welders in the firing line simply make a small tack, first on one side, and start welding on the other side as they come to each joint. This demands, however, coordination and good management, so that the line-up gang and welding crew are close together without causing delays, since expansion and contraction of pipe lined up too far ahead of welding will cause separation of the joint.

In regard to cost, there naturally are many conflicting opinions, as brought out in the discussion. Although the bonus system has been often used to produce higher weld quality with gratifying results, I know of only one case where the bonus has been tried to speed up welding with gas construction. The results have been quite phenomenal. Although, as pointed out by Mr. Price, the bonus may be used as a managerial means of reducing lost motion and of speeding operations, it nevertheless is necessary, in the very nature of things, to increase materially the inspection to maintain quality. This should be kept in view and is no small item to be neglected.

There are a great many factors that constitute and influence the cost of welding other than the mere speed of welding or materials used. The country through which the line is running and the weather are more important, if not the most important, single items effecting cost. As Mr. Price stated, for instance, in some country, through certain kinds of territory, where a great deal of bending of the pipe is necessary, he obtained as low as one weld per day per welder in the tie-in, on the other hand, when the going was good, he obtained the usual expected number.

It can be seen that there are so many factors involved, as weather, kind of country, investment in equipment, repair and transportation of equipment, transportation of men, accessibility of material and

labor, camp expense, efficiency of management, and numerous others, that it is very difficult to draw any positive comparison between two jobs, or between the two processes. Only in two parallel lines could a comparison be positive. I think, in discussion of this subject, these factors should be taken into consideration.

Mr. Candy: I would like to ask one more snappy question. Mr. Speller raised a point that corrosion apparently does not affect the pipe line very much in the factor of safety, due to coatings upon the outside pipe line. I am wondering if all corrosion is on the outside. Maybe corrosion takes place on the inside. My experience has been the gas tanks of my cars have been corroded on the inside as much as on the outside.

Chairman Lincoln: This discussion which the papers have provoked has been very interesting and very instructive. We have to close the discussion now because we have a third paper. The third paper is on a somewhat different subject. It is on "The Welding of Tubing and Pipes for Locomotives and Boilers," by Mr. Woofter of the Swift Electric Co. I have great pleasure in introducing Mr. Woofter.

Discussion paper "Welding of Tubing and Pipes for Locomotives and Boilers,"* by H. Woofter, Swift Electric Co.

Mr. Speller: This paper is so wide in scope that a number of points might be discussed to advantage. I will only attempt to discuss one apparent omission in connection with the application of welding to locomotive construction. The speaker properly refers to the importance of welding in connection with the setting of boiler tubes, but has said nothing of the application of welding of piping in other parts of the locomotive. The problem of the best system of piping for locomotives is very pressing. A railroad operating manager told me a few years ago that 90 per cent of the train detentions in one section of his system were due to breakage of pipe at threaded joints. Those figures may sound a little large, but this has been a serious problem for some time and various solutions have been suggested. Fusion welding may be the best remedy so as to avoid threaded joints as far as practicable, and I believe that it is now being tried out on some of the railroads. Now that seamless pipe is so generally available in all sizes, a considerable reduction in weight can be affected by using welded seamless instead of extra strong wrought iron or steel threaded pipe. There is a certain amount of corrosion around a locomotive and the threaded joint presents a good opportunity for corrosion fatigue. It is difficult to keep threaded joints clamped tightly so that there will be no vibratory stress at the thread.

Mr. Woofter: I was only able, in the time I had, to touch on a few of the high spots. There are many places where welding can be used on locomotives which I had no opportunity to speak about because of lack of time.

Chairman Lincoln: This paper is one of very great interest. If any of you have gone through the Ford factory, for instance, you will

*Paper published in the October, 1929 issue Journal of the A. W. S.

realize what a tremendously important thing resistance welding is. Thousands of welds are being made up there, and a good many people are riding in cars in which these welds are made, and I am struck by Mr. Woofter's remark that due to these welding machines usually being located in factories, the general public is possibly not as well acquainted with the importance of this process as the general public is with the process of arc welding, where that work is done in the sight of thousands of people. I am sorry the time is so short.

Mr. Henry Hobart: May I ask a question? I understand the modern tendency is to use very large current in much shorter time than previously used in a longer time.

Mr. Woofter: It is the opposite. With the old process the work was shoved together and the current allowed to flow across and the heating occurred in accordance with the I^2R formula, wherein the I^2 square was very large. Now the work is brought close together and the current begins to jump over the minute air gap between the work. Although the air gap is small, the resistance is ten times greater, and the I^2 much smaller.

Chairman Lincoln: I would like to ask Mr. Woofter if the voltage on the flash welding transformers is higher or lower than on low resistance welding, such as was used twenty-five years ago.

Mr. Woofter: In the old resistance welders, as designed by W. S. Moody and Herman Lemp, they used low voltages and took a good bit of time, a minute or a minute and a half, to make a large butt weld. Just why, I don't know, except perhaps production was not so pressing as now; labor was cheaper than now, and it may be they didn't realize at that time that higher voltages could be used. Now, however, instead of using one and a half or two volts across the work, we use eight or ten, or twelve, or fifteen volts, depending upon the particular job at hand, and other conditions entering into it. Now, instead of forcing the work together and letting the current flow through and heat slowly, the enormous heat of the arc is utilized, which heats it up quicker and, when forced together quickly, makes a stronger weld. In the old butt-weld oxides were compressed and imprisoned in the weld, and no flash was thrown out. Now the flash throws off the oxides.

Mr. Hobart: That is the point I wanted to lead around to; that it is a great deal quicker and it is metallographically better.

Mr. Woofter: I might say that the total arc consumed is only about 40 per cent as much as in the butt-welding, and the butt-weld, instead of showing 90 per cent of the strength of the parent metal, is 100 per cent, so we have improved in the smaller amount of current used, and strength of weld.

Mr. H. M. Hobart: Both in the thermit process and in the resistance process, the weld is made almost instantaneously. To cut down the time of doing anything usually cuts down the cost. I want to ask Mr. Woofter if he confirms my opinion that this almost instantaneous effecting of the weld is a very important factor in obtaining good welds as disclosed both by mechanical tests, tensile, bending and fatigue, and by metallographical examinations.

Chairman Lincoln: I presume Mr. Hobart's point is that the old process, taking a minute to make a weld, the watt-hours used in that minute, would be very much greater in a weld which used a larger power for a very much shorter time. Isn't that true, that the power used in the present flash weld, while the power is being applied, is greater than it was in the old time weld? The weld is made in so much shorter time that the watt-hours are reduced.

Mr. Woofter: I might state in the automobile rim, the weld is made in four-fifths of a second. It is made on 300 to 200 Kv.a., whereas in ten seconds you make that weld under 20 Kv.a.

H. M. Hobart: I wanted to establish the general conclusion that ALL methods of welding give better results (other things being equal) the more quickly the weld is made. It is made almost instantaneously in the thermit and resistance processes. But it has been my experience that after skill has been acquired with the use of heavy currents in the arc process, the results have been better than with smaller currents, and I believe we should go much farther in developing the arc process along the lines of the very rapid application of large amounts of heat. Progress in this direction should be with automatic machines.

Chairman Lincoln: Any further discussion? If not, the meeting will stand adjourned.

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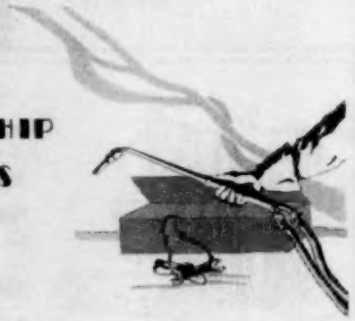

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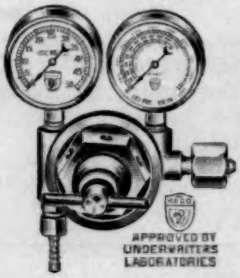

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Nomenclature, Definitions and Symbols

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AMERICAN WELDING SOCIETY

Committee on Nomenclature, Definitions and Symbols

INTRODUCTION

In every trade or profession a standard terminology is essential to a clear understanding of written and graphical records. As there are no accepted standards, at the present time, for many of the terms and symbols used in connection with the various welding and cutting processes, the executive committee of the American Welding Society, at its meeting of Dec. 21, 1926, authorized the appointment of a Committee on Nomenclature, Definitions and Symbols.

This committee has prepared and herewith submits its report on these standards which it is believed will meet the present needs of industry. However, as all definitions are not necessarily universal in the practical application of standards, it may be necessary to restrict some of the definitions given in these standards to suit conditions peculiar to the various fields in which welding is used.

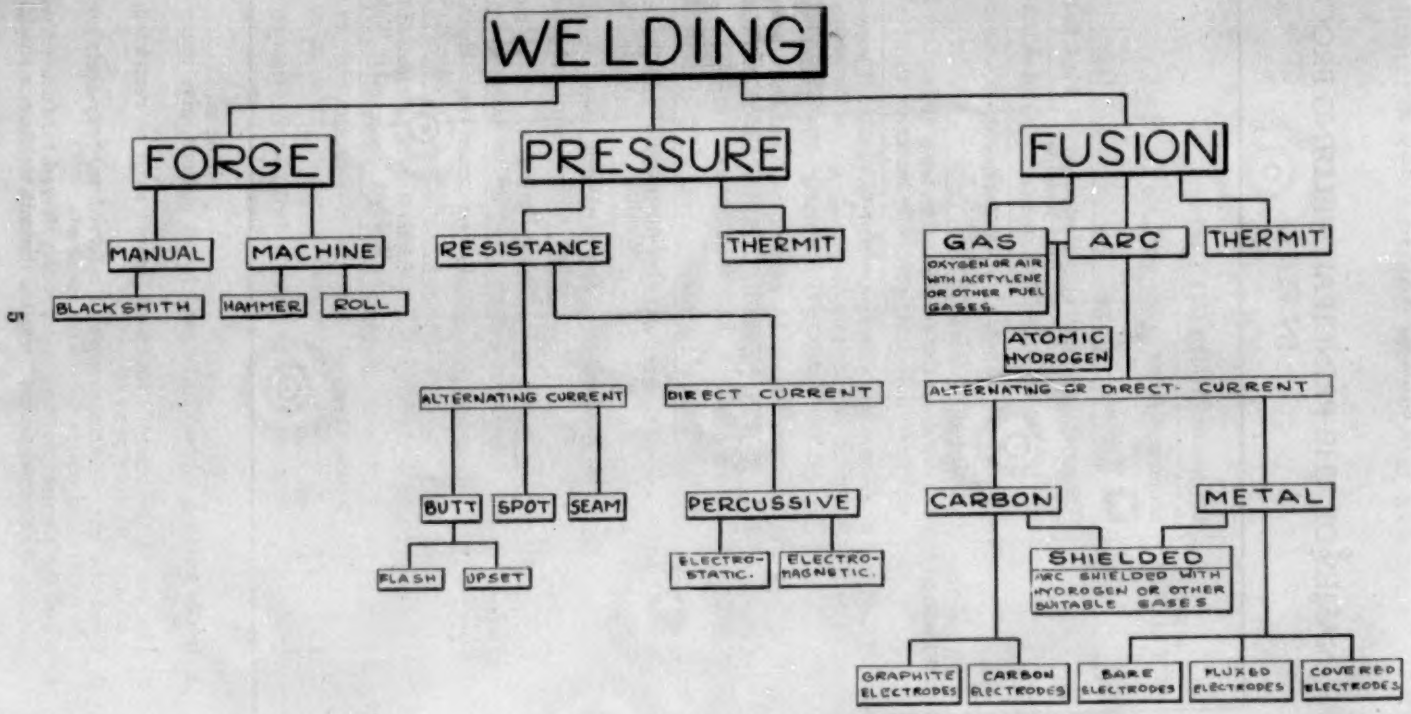
The committee considers the Standards tentative and will appreciate any comments or criticisms which will lead to their improvement. It is hoped that these Standards will be used in the design of welded structures and in the preparation of technical papers.

The committee desires to express its appreciation to the Newport News Shipbuilding and Dry Dock Co. for its technical and clerical assistance in the preparation of the cuts and manuscript, also to the President of the Society, Mr. F. T. Llewellyn, and Mr. F. M. Farmer, Chairman of the Committee on Standard Tests for Welds, for many valuable suggestions.

NOTE:—*Definitions of terms relating to the physical properties of materials* will be found in circular No. 101 of the U. S. Bureau of Standards, and *definitions of terms relating to heat treatment operations* in the following publications of the American Society for Testing Materials: Proceedings, Vol. 27, Part I, p. 703 (1927); 1927 Book of Tentative Standards, page 88; and Report of Committee A-4 on "Heat Treatment of Iron and Steel," submitted at the 1928 annual meeting.

SECTION I

NOMENCLATURE



NAMES OF THE PRINCIPAL WELDING PROCESSES IN FULL

FORGE WELDING	Blacksmith Welding		
	Hammer Welding		
	Roll Welding		
PRESSURE WELDING	Resistance Welding	Resistance Butt Welding	Flash Butt Welding
			Upset Butt Welding
		Spot Welding (See Note No. 2)	
		Seam Welding (See Note No. 2)	
		Percussive Welding	Electro-Static Percussive Welding
			Electro-Magnetic Percussive Welding
	Pressure Thermit Welding (See Note No. 4)		
FUSION WELDING	Gas Welding (See Note No. 3)	Oxy-Acetylene Welding	
		Oxy-Hydrogen Welding	
		Atomic Hydrogen Welding	
	Arc Welding	Carbon Arc Welding	Shielded Carbon Arc Welding
		Metal Arc Welding	Shielded Metal Arc Welding
	Fusion Thermit Welding (See Note No. 4)		

NOTE:—

1. If the welding process to be used is not obvious, give name of process in full.
2. The use of the terms "spot" and "seam" shall be restricted to the resistance welding process.
3. When the gas welding process is referred to, "oxy-acetylene" welding is understood unless otherwise specified.
4. When the thermit welding process is referred to, fusion thermit welding is understood unless pressure thermit welding is specified.

SECTION II

DEFINITIONS

A—GENERAL TERMS

(a) Welding; (b) Cutting; (c) Miscellaneous

(a) General Welding Terms

1. *Weld:* A localized consolidation of metals.

2. *Welding Process:* The method used to produce a weld.

3. *Forge Welding:* A process of welding metals in the plastic state by means of manual or mechanical hammering. This process includes Blacksmith Welding, Hammer Welding and Roll Welding.

4. *Pressure Welding:* A process of welding metals in the highly plastic and/or molten states by means of mechanical pressure. This process includes Resistance and Pressure Thermit Welding.

5. *Fusion Welding:* A process of welding metals in the molten, or molten and vaporous state without the application of mechanical pressure or blows. This process includes Gas, Arc and Fusion Thermit Welding.

6. *Base Metal:* The parent material welded or cut.

7. *Joint:* That portion of a structure wherein separate base metal parts are united.

8. *Welded Joint:* A joint wherein separate base metal parts are united by one or more independent welds.

9. *Type of Joint:* Joint classification based on the relative movement and/or deformation of its parts during welding.

10. *Form of Joint:* Joint classification based on the arrangement and cross sectional shape of the component parts of the joint, irrespective of the form or number of welds used to joint said parts.

11. *Composite Joint:* A joint wherein welding or some other thermal process of joining metals is used in conjunction with a mechanical process to unite the separate base metal parts. Fig. 1.

12. *Composite Structure:* A structure wherein more than one method of joining its parts is used. Fig. 1.

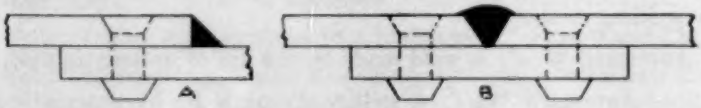


Fig 1

13. *Closed Joint:* A generic term applied to a joint having its edges or surfaces in contact during welding. Fig. 2.

14. *Open Joint:* A generic term applied to a joint having its edges or surfaces spaced apart. Fig. 3.

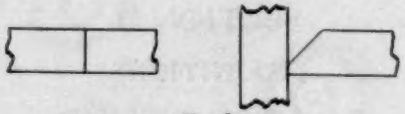


Fig 2

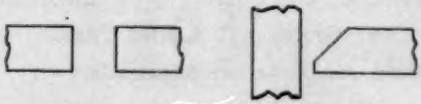


Fig 3

15. *Edge Joint:* A generic term applied to a joint obtained by the placement of a surface of one base metal part on a surface of another base metal part in such a manner that the weld joining the parts is within the outer surface planes of both of the parts joined. Fig. 4.

16. *Butt Joint:* A generic term applied to a form of joint obtained by the placement of one base metal part on another base metal part, in such a manner that the weld joining the parts is between the surface planes of both of the parts joined. Fig. 5.

17. *Lap Joint:* A generic term applied to a form of joint obtained by the overlapping of base metal parts, the overlapping surfaces being in the same plane. Fig. 6.

18. *Corner Joint:* A generic term applied to a form of joint obtained by the angular placement of an edge of one base metal part on an edge or surface of another base metal part in such a manner that neither part extends beyond the outer surface plane of the other part joined. Fig. 7.

19. *Tee Joint:* A generic term applied to a form of joint obtained by the angular placement of an edge of one base metal part on a surface of another base metal part in such a manner that this surface extends on both sides of the joint. Fig. 8.

20. *Form of Weld:* Weld classification based on the arrangement and cross sectional shape of its component base metal parts, irrespective of the type or form of joint in which it is incorporated.

21. *Manual Weld:* A weld made by an operator unaided by mechanically guided welding tools.

22. *Automatic Weld:* A weld made by the aid of automatic equipment.

23. *Semi-Automatic Weld:* A weld made partially by automatic equipment and partially by manual means.

24. *Full Automatic Weld:* A weld made entirely by automatic equipment.

25. *Root:* The zone at the bottom of the cross-sectional space provided to contain a fusion weld. Figs. 9 and 13.

26. *Root Edge:* The joint edge at the bottom of the cross sectional space provided to contain a fusion weld. Fig. 10.

27. *Root Face: A* joint surface of relatively small dimensions at the bottom of the cross sectional space provided to contain a weld. Fig. 11.

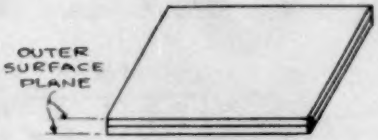


Fig 4
EDGE JOINT

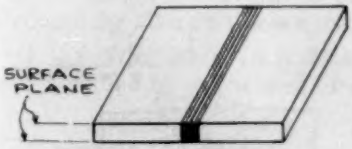


Fig 5
BUTT JOINT

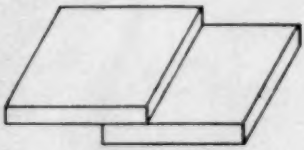


Fig 6
LAP JOINT

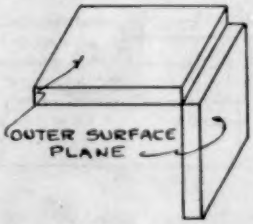


Fig 7
CORNER JOINT

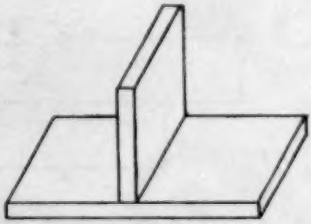


Fig 8
TEE JOINT

28. *Throat:* The minimum thickness of a fusion weld along a straight line passing through its root. Figs. 9 and 13. Note: This definition is sometimes restricted so as to specifically exclude reinforcement.

29. *Face:* The exposed surfaces of a fusion weld. Figs. 9 and 13.

30. *Toe:* The edge of a fusion weld formed by the intersection of a face and the base metal. Figs. 9 and 13.

31. *Layer:* A stratum of weld metal of a fusion weld and consisting of one or more beads depending on the dimensions of the weld and the welding technic employed. Fig. 12.

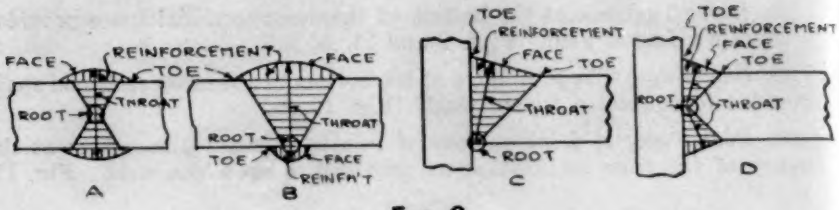


Fig 9

Fig 10

Fig 11

Fig 12

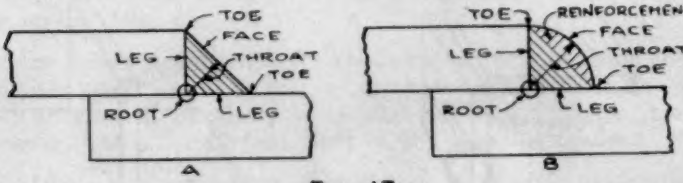


Fig 13

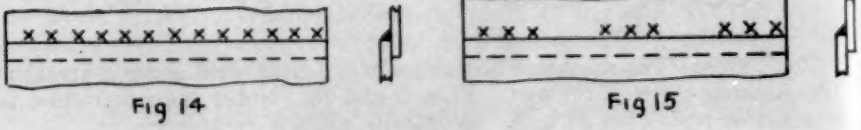


Fig 14

Fig 15

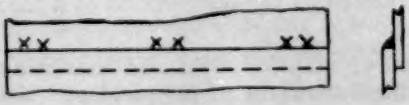


Fig 16

32. *Leg:* One of the fusion surfaces of a fillet weld. Fig. 13.

33. *Continuity:* A term used to designate the linear distribution of a weld in a welded joint.

34. *Continuous Weld:* A weld of unbroken continuity. Fig. 14. Note: All welds are understood to be continuous unless otherwise specified.

35. *Intermittent Weld:* A weld of broken continuity. Fig. 15.

36. *Tack Weld:* An intermittent weld used for assembly purposes only. Fig. 16.

37. *Strength Weld:* A weld intended to develop a predetermined strength.

38 *Caulk Weld:* A weld intended to seal a joint.

39. *Composite Weld:* A weld complying with the requirements for both strength and caulk welds.

40. *Ripple Weld:* A gas or arc weld having a surface similar to that produced by dropping a stone into still water.

41. *Finished Weld:* A weld, the natural exposed surface of which has been modified by mechanical or thermal means to improve its appearance.

Fig 17 Fig 19

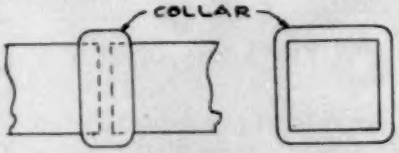


Fig 18

42. *Flush:* A term applied to the exposed surfaces of fusion butt welds when the surface of the weld is even with at least one of the surfaces of the base metal parts joined. Fig. 17.

43. *Reinforcement:* Weld metal in excess of that required for standard fillet and flush butt welds. Figs. 9 and 13.

44. *Reinforced:* A term applied to a weld provided with reinforcement.

45. *Collar:* The excess metal of a completed fusion thermit weld. Fig. 18.

46. *Concave:* A term applied to a fusion butt weld when its throat thickness is less than the thickness of the thinner part joined, and to a fillet weld when its throat thickness is less than the thickness of the throat of a standard fillet weld. Fig. 19.

47. *Flat Weld:* A butt or fillet weld made by the fusion welding process with its linear direction horizontal or inclined at an angle of 45° or less

to the horizontal, the weld being made from the upper or top side of the parts joined. Fig. 20.

48. *Vertical Weld:* A butt or fillet weld made by the fusion welding process with its linear direction vertical or inclined at an angle less than 45° to the vertical. Fig. 21.

49. *Overhead Weld:* A butt or fillet weld made by the fusion welding process with its linear direction horizontal or inclined to an angle less than 45° to the horizontal, the weld being made from the lower or under side of the parts joined. Fig. 22.

50. *Horizontal Weld:* A bead or a butt weld made by the fusion welding process with its linear direction horizontal or inclined at an angle

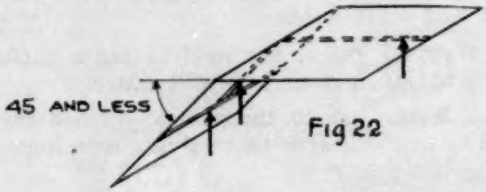


Fig 22

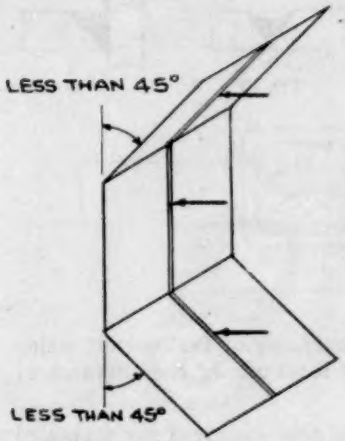


Fig 21

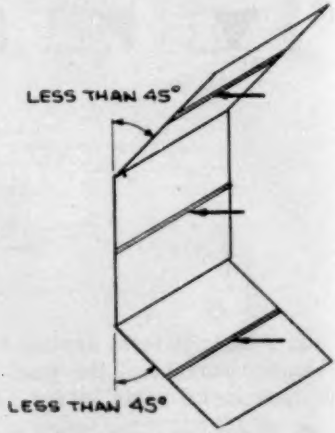


Fig 23

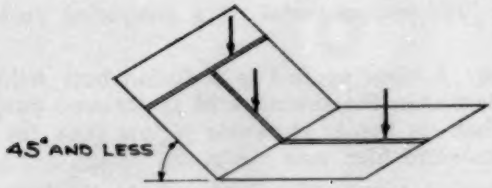


Fig 20

less than 45° to the horizontal, the parts welded being vertically or approximately vertically disposed. Fig. 23.

51. *Edge Weld:* A generic form of weld whose throat lies in a plane disposed approximately in the same plane as the surfaces of the parts joined. Fig. 24.

52. *Butt Weld:* A generic form of weld whose throat lies in a plane disposed approximately ninety degrees (90°) with respect to the surfaces of at least one of the parts joined. Fig. 25.

53. *Fillet Weld:* A generic form of fusion weld of approximately triangular cross section, and whose throat lies in a plane disposed approximately forty-five degrees (45°) with respect to the surfaces of the parts joined. Fig. 26.

Fig 24

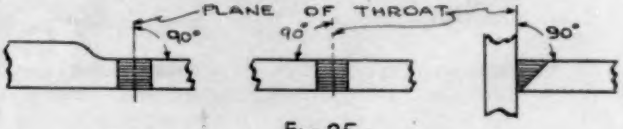


Fig 25

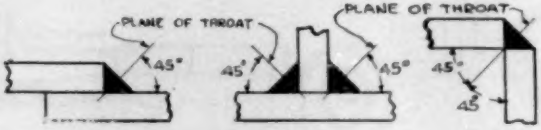


Fig 26

54. *Filler Metal:* Material specially prepared for addition to the weld in some forms of the fusion welding processes (See welding rod, electrode and thermit mixture).

55. *Weld Metal:* The material composing the weld. (See Weld Metal Zone, Deposited Metal Zone, and Fusion Zone.)

56. *Deposited Metal:* Filler metal which has been melted by a fusion welding process. (See Filler metal.)

57. *Weld Metal Zone:* That portion or area of a weld which has been heated to the plastic, molten and/or vapor states. Fig. 27.

58. *Fusion Zone:* That portion or area of the weld metal zone bordering on the unmelted base metal. Fig. 27.

59. *Deposited Metal Zone:* That portion or area of the weld metal zone of a fusion weld external to the original surface and/or edge planes provided for the weld and consisting substantially of deposited metal. Fig. 27.

60. *Refined Zone:* That portion or area of the base metal bordering on the fusion zone wherein grain refinement has taken place due to the welding heat. Fig. 27.

61. *Unaffected Zone:* That portion or area of the base metal outside of the refined zone wherein no change in grain size has taken place. Fig. 27.

62. *Weld Penetration:* A dimensional expression of the depth of the fusion zone below the original surface and/or edge planes of the base metal.

63. *Heat Penetration:* The combined depths of the fusion and refined zones below the original surface and/or edge planes of the base metal.

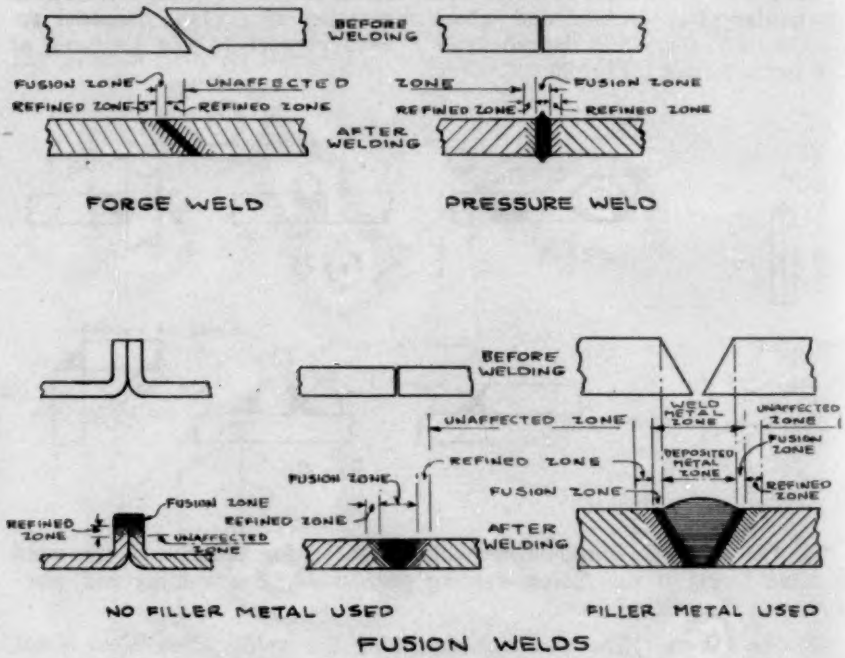


Fig 27

64. *Crater:* A convex depression in the fusion area of a weld indicating the depth of fusion.

65. *Gas Pocket:* A cavity in a weld caused by the trapping of gases liberated by the metal when cooling.

66. *Slag Inclusion:* Non-metallic material entrapped in the weld.

67. *Neutral Flame:* A welding flame wherein the correct proportions of gases are supplied to the flame for perfect combustion. Fig 28.

68. *Carbonizing Flame:* A welding flame having acetylene in excess of that required to produce a neutral flame. Fig. 29.

69. *Oxidizing Flame:* A welding flame having oxygen in excess of that required to produce a neutral flame. Fig. 30.

70. *Cone:* That part of the welding flame which is conical in shape and next to the orifice of the tip. This is the hottest part of the flame. Figs. 28 and 30.

71. *Back Fire:* Momentary retrogression of a torch flame into the torch tip, the gases reigniting immediately following the withdrawal of the tip from the work although the use of a lighter is sometimes necessary. In either case no adjustment of the torch valves is required. Sometimes termed *Preignition.*

72. *Flashback:* Retrogression of a torch flame into the mixing chamber or acetylene passage of the torch accompanied by a hissing or squealing sound and a smoky, sharp-pointed flame of small volume, necessitating the immediate cutting off of the gas supply to prevent excessive heating and possible destruction of the torch head. A flashback usually requires the torch head to be cooled before the torch is relighted.

73. *Rate of Flame Propagation:* The speed at which a mixture of gases burn.

74. *Thermit Reaction:* The self-propagating exothermic reaction between iron oxide and aluminum which results in the formation of highly superheated liquid iron and aluminum oxide.

Fig 28

Fig 29

Fig 30

75. *Weld Size:* A dimensional expression of the cross section designed value of the weld. The size of a fillet weld made by the gas and arc welding processes is the designed length of its legs, and the size of a butt weld, made by the gas and arc welding processes, is its net or unreinforced throat dimension in inches.

76. *Weld Length:* A dimensional expression of the unbroken length of the weld. The length of a gas or arc weld is the length of the full cross section of the weld, exclusive of the length of any craters.

77. *Thermal Stress:* The stress or stresses produced in a welded joint, welded structure or part cut by the heat of welding or cutting.

78. *Residual Stress:* The stress or stresses remaining in a welded joint, welded structure or part cut on completion of welding or cutting.

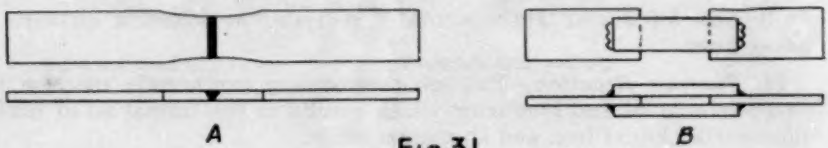


Fig 31

Fig 32

79. *Test Specimen:* Material specially prepared for test purposes.

80. *Base Metal Test Specimen:* A test specimen composed wholly of base metal.

81. *Filler Metal Test Specimen:* A test specimen composed wholly of filler metal.

82. *Weld Metal Test Specimen:* A test specimen having one or more welds with component base metal parts so shaped as to compel failure to take place in the weld metal. Fig. 31.

83. *Welded Joint Test Specimen:* A test specimen having one or more welds and primarily intended to compare the strength of the welded joint with that of the base metal.

84. *Deposited Metal Test Specimen:* A test specimen substantially composed of deposited metal. Fig. 32.

85. *Soldering:* The coating in the molten state of an alloy of lead and tin on the surface of metals of a higher melting point. This process is used to coat the surface of metals or to join separate base metal parts.

86. *Brazing:* The amalgamation in the molten state of soft brass with

the surface of metals of a higher melting point. It is a hard soldering process, and is sometimes used to build up a surface layer of brass or to join separate ferrous and/or non-ferrous base metal parts.

87. *Bronze Welding:* A trade term for the application of bronze or brass to base metal of a higher melting point in essentially the same manner as in fusion welding.

(b) General Cutting Terms

1. *Cut:* The severing of metals by chemical and/or thermal means, viz: Gas Cutting, Carbon Arc Cutting and Metal Arc Cutting.

2. *Cutting Process:* The means or methods used to produce a cut.

3. *Gas Cutting:* The process of severing ferrous metals by means of the chemical behavior of oxygen in the presence of ferrous metals at high temperatures, to produce a kerf or cut of uniform width without burning the edges of the kerf or cut.

4. *Carbon Arc Cutting:* The process of severing ferrous and non-ferrous metals by melting with the heat of the carbon arc.

5. *Metal Arc Cutting:* The process of severing ferrous and non-ferrous metals by melting with the heat of the metal arc.

6. *Kerf:* The space from which the metal has been removed by the cutting torch.

NOTE: The following terms are defined in the section on "General Welding Terms."

Base Metal ..... Page 7
Thermal Stress ..... Page 16
Residual Stress ..... Page 16
Back Fire ..... Page 15
Flash Back ..... Page 15
Rate of Flame Propagation ..... Page 15

(c) Miscellaneous Terms

1. *Constant Voltage Welding Source:* A source of electric power which automatically maintains its voltage within 5 per cent of the rated full-load setting over the range from full load to no load and has a time of recovery of not more than 0.3 second.

2. *Variable-Voltage Welding Source:* A source of electric power, the voltage of which automatically reduces as the current increases but not in such a way as to qualify the source as a constant-energy source.

3. *Constant-Current Welding Source:* A source of electric power which, when adjusted to give rated current output with normal arc voltage, will automatically maintain this current output within 5 per cent of the rated value with a variation in arc voltage of 10 per cent above or below the normal arc voltage and has a time of recovery of not more than 0.3 second.

4. *Constant-Power Welding Source:* A source of electric power which, when adjusted to give rated power output with normal arc voltage will automatically maintain this power output within 5 per cent of the rated value with a variation in arc voltage of 10 per cent above or below the

normal arc voltage and has a time of recovery of not more than 0.3 second.

5. *Direct Current:* A unidirectional current. As ordinarily used, the term designates a practically non-pulsating current.

6. *Alternating Current:* A current, the direction of which reverses at regularly recurring intervals. Unless distinctly otherwise specified, the term alternating current refers to a periodically varying current with successive half waves of the same shape and area.

7. *Anode Drop:* The voltage drop between the arc stream and the positive electrode.

8. *Cathode Drop:* The voltage drop between the arc stream and the negative electrode.

9. *Arc Stream Voltage:* That voltage across the gaseous zone which varies with the length of the arc.

10. *Open Circuit Voltage:* The voltage of a welding circuit between the electrodes when no current is flowing.

11. *True Arc Voltage:* The summation of the arc stream voltage, the cathode drop and the anode drop. It is determined by deducting from the welding arc voltage the drop in the electrode.

12. *Welding Arc Voltage:* The total voltage between the electrode holder and the base metal immediately adjacent to the arc terminal. It is the summation of the arc stream voltage, the cathode drop, the anode drop and the drop in the electrode.*

13. *Time of Recovery:* The time required to assume conditions to within 5 per cent of their final value in an automatically regulated welding circuit after a definitely specified disturbance has taken place.

The time of recovery of a welding generator is measured as follows: Insert resistance in the welding circuit of such value that normal full-load terminal voltage of the machine is registered across it at full-load current; short-circuit one-half of the resistance and allow conditions to become stable; then instantly remove the short circuit. The time required for the current and voltage to return to within 5 per cent of their original values is the time of recovery.

B—PROCESSES

(a) Forge Welding (b) Pressure Welding (c) Fusion Welding

(a) Forge Welding Processes

1. *Blacksmith Welding:* A Forge Welding process which utilizes manual hammering.
2. *Hammer Welding:* A Forge Welding process which utilizes mechanical hammering.
3. *Roll Welding:* A Forge Welding process which utilizes mechanically operated pressure rolls.

*In the case of the Zerener process employing two electrodes the welding arc voltage is the total voltage between the two electrode holders.

(b) PRESSURE WELDING PROCESSES

1. *Resistance Welding:* A pressure welding process wherein the welding heat is obtained by passing an electric current across the resistance set up between the contact areas to be welded.

2. *Pressure Thermit Welding:* A pressure welding process wherein the welding heat is obtained from the liquid products of a thermit reaction. (See Thermit Reaction.)

3. *Resistance Butt Welding:* A resistance welding process wherein a butt joint is employed. Fig. 33.

4. *Seam Welding:* A resistance welding process wherein the weld is made linearly between two contact rollers, a contact roller and a contact bar, on contact points. Fig. 34.

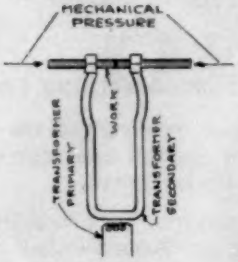


Fig 33

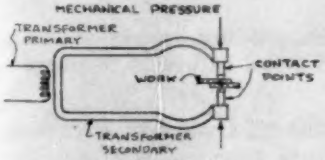


Fig 35

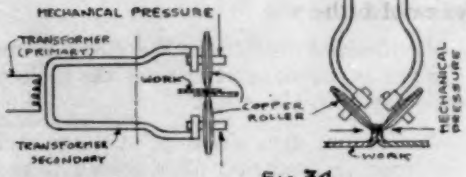


Fig 34

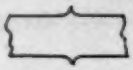


Fig 36

Fig 37

5. *Spot Welding:* A resistance welding process wherein the weld is made in one or more spots by the localization of the electric current between contact points. Fig. 35.

6. *Percussive Welding:* A resistance welding process wherein the electric current is suddenly discharged across the contact area or areas to be welded and a hammer blow is applied simultaneously or immediately following the electrical discharge.

7. *Flash Butt Welding:* A resistance butt welding process wherein the weld is quickly made by a light contact pressure followed by a period of arcing with no pressure applied and finished with heavy pressure, some of the liquefied metal being thrown out in the form of a flash. Fig. 36.

8. *Upset Butt Welding:* A resistance butt welding process wherein the weld is made by a continuous contact pressure with only enough heat to bring the pieces to a plastic state and the weld is completed with considerable pressure producing an upset at the joint. Fig. 37.

9. *Electro-Static Percussive Welding:* A percussive welding process wherein a condenser is used to supply the arc energy.

10. *Electro-Magnetic Percussive Welding:* A percussive welding process wherein the stored energy in a magnetic field is transformed by the collapse of the field to supply the energy.

(c) Fusion Welding Processes

1. *Gas Welding:* A fusion welding process wherein the welding heat is obtained from a gas flame, oxygen and acetylene being understood to be the gases used unless otherwise stated.

2. *Arc Welding:* A fusion welding process wherein the welding heat is obtained from an electric arc formed either between the base metal and an electrode, or between two electrodes, with or without the use of gases.

3. *Metal Arc Welding:* An arc welding process wherein the electrode used is a metal rod or wire, which, when melted by the arc, supplies the filler metal in the weld.

4. *Shielded Metal Arc Welding:* A metal arc welding process wherein the arc is surrounded by, and the molten weld metal bathed in, hydrogen or other suitable gases.

5. *Carbon Arc Welding:* An arc welding process wherein a carbon electrode is used and filler metal, if required, is supplied by a welding rod as in gas welding.

6. *Shielded Carbon Arc Welding:* A carbon arc welding process wherein the arc is surrounded by and the molten weld metal bathed in hydrogen or other suitable gases.

7. *Atomic Hydrogen Welding:* A fusion welding process wherein the heat of an electric arc between two suitable electrodes is used to dissociate molecular hydrogen into its atomic form, which, on recombining in the molecular form, gives up the energy required to dissociate it, producing a flame of very high temperature, at the same time bathing the molten weld metal in hydrogen. It may be considered as a combination of the gas and arc welding processes.

8. *Fusion Thermit Welding:* A fusion welding process wherein the welding heat is obtained from liquid steel produced by a thermit reaction, and the filler metal is supplied by the steel produced in this reaction.

C—FORMS OF JOINT

(a) Forge Welding (b) Pressure Welding (c) Fusion Welding

(a) Forms of Joints Used in the Forge Welding Process

1. *Scarf Joint:* A lap joint used in the forge welding process wherein the abutting ends to be welded are upset in the same plane at an angle of approximately 45 deg. to the longitudinal axis of the parts to be joined. Fig. 38.

Fig 38

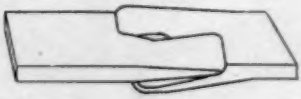
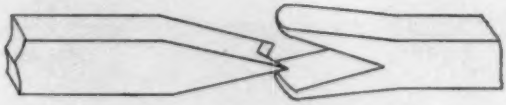


Fig 39



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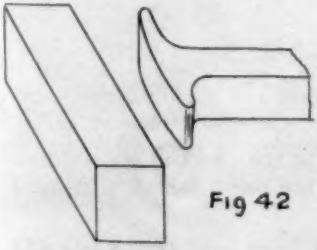


Fig 42

Fig 41

2. *Split Joint:* A lap joint used in the forge welding process wherein the abutting ends of parts to be welded are tapered, split and interlocked. Fig. 39.

3. *"V" Joint:* A lap joint used in the forge welding process wherein the abutting ends of one of the parts to be welded are respectively wedge and "V" shaped. Fig. 40.

4. *Plain Butt Joint:* A butt joint used in the forge welding process wherein the abutting ends of the parts to be welded are upset at approximately 90 deg. with respect to the longitudinal axis of the parts to be joined. Fig. 41.

5. *Jump Butt Joint:* A butt joint used in the forge welding process wherein the abutting end of one of the parts to be welded is upset out-

ward in opposite directions at right angles to its longitudinal axis. Fig. 42.

(b) FORMS OF JOINTS USED IN THE PRESSURE WELDING PROCESSES

NOTE: As joints and welds in these processes are more or less synonymous, all parts joined have been classified as "welds" and are defined in Section D (b), pages 28 to 30 inclusive.

(c) FORMS OF JOINTS USED IN THE FUSION WELDING PROCESSES

1. *Leaf Edge Joint:* An edge joint used in the gas and arc welding processes wherein the parts are flanged into the same plane on completion of welding. Fig. 43.

Fig 43

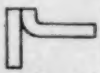


Fig 44

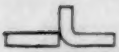
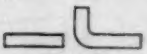


Fig 45



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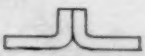

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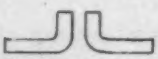

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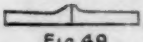


Fig 49

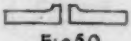


Fig 50

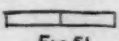


Fig 51

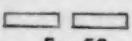


Fig 52

2. *Flanged Edge Joint:* An edge joint used in the gas and arc welding processes wherein the abutting end of one of the parts joined is flanged prior to welding. Fig. 44.

3. *Closed Single Flanged Butt Joint:* A butt joint used in the gas and arc welding processes wherein the abutting end of one of the parts joined is flanged and in contact with the edge of the other part during welding. Fig. 45.

4. *Open Single Flanged Butt Joint:* A butt joint used in the gas and arc welding processes wherein the abutting end of one of the parts joined is flanged and separated from the edge of the other part. Fig. 46.

5. *Closed Double Flanged Butt Joint:* A butt joint used in the gas and arc welding processes wherein the abutting ends of both parts are flanged on the same side of the joint and in contact during welding. Fig. 47.

6. *Open Double Flanged Butt Joint:* A butt joint used in the gas and arc welding processes wherein the abutting ends of both parts are flanged on the same side of the joint and separated. Fig. 48.

7. *Closed Upset Butt Joint:* A butt joint used in the gas and arc welding processes wherein both abutting edges are upset on the same side of the joint and in contact during welding. Fig. 49.

8. *Open Upset Butt Joint:* A butt joint used in the gas and arc welding processes wherein both abutting edges are upset on the same side of the joint and separated. Fig. 50.

9. *Closed Square Butt Joint:* A butt joint used in the gas, arc and pressure thermit welding processes wherein the joint edges are disposed approximately 90 deg. with respect to the surface planes and in contact during welding. Fig. 51.

10. *Open Square Butt Joint:* A butt joint used in the gas, arc and fusion thermit welding processes wherein the joint edges are disposed approximately 90 deg. with respect to the surface planes and separated. Fig. 52.

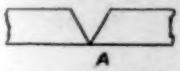


Fig 53

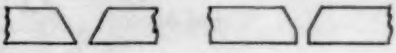


Fig 54

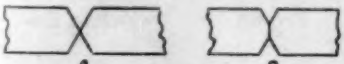


Fig 55

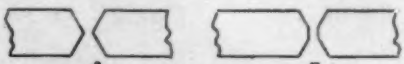


Fig 56

11. *Closed Single V Butt Joint:* A butt joint used in the gas and arc welding processes wherein the joint edges are beveled so as to inclose a "V" approximately symetrically disposed with respect to the longitudinal axis of the joint, the root edges or root faces of which are in contact during welding. Fig. 53.

12. *Open Single "V" Butt Joint:* A butt joint used in the gas and arc welding processes wherein the joint edges are beveled so as to inclose a "V" approximately symetrically disposed with respect to the longitudinal axis of the joint, the root edges or root faces of which are separated. Fig. 54.

13. *Closed Double "V" Butt Joint:* A butt joint used in the gas and arc welding processes having both joint edges beveled on both sides, forming two independent V's, approximately symetrically disposed about the longitudinal axis of the joint, the root edges or root faces of which are in contact during welding. Fig. 55.

14. *Open Double V Butt Joint:* A butt joint used in the gas and arc welding processes, having both edges beveled on both sides, forming two independent V's, approximately symetrically disposed about the longitudinal axis of the joint, the root edges or root faces of which are separated. Fig. 56.

15. *Closed Single Bevel Butt Joint:* A butt joint used in the gas and arc welding processes having the joint edge of one part beveled, and its root edge or root face in contact with the opposite square surface during welding. Fig. 57.

16. *Open Single Bevel Butt Joint:* A butt joint used in the gas and arc welding processes, having the joint edge of one part beveled and its root edge or root face separated from the opposite square surface. Fig. 58.

17. *Closed Double Bevel Butt Joint:* A butt joint used in the gas and arc welding processes, having the joint edge of one part beveled from both sides and its root edge or root face in contact with the opposite square surface during welding. Fig. 59.

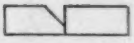


Fig 57

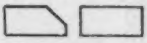


Fig 58

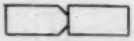


Fig 59

Fig 60

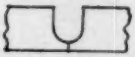


Fig 61

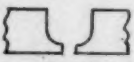


Fig 62

Fig 63

Fig 64

18. *Open Double Bevel Butt Joint:* A butt joint used in the gas, arc and fusion thermit welding processes, having the joint edge of one part beveled from both sides, and its root edge or root face separated from the opposite square surface. Fig. 60.

19. *Closed Single U Butt Joint:* A butt joint used in the gas and arc welding processes, wherein the joint edges are prepared from one side so as to inclose a U, approximately symetrically disposed with respect to the longitudinal axis of the joint and its root faces in contact during welding. Fig. 61.

20. *Open Single U Butt Joint:* A butt joint used in the gas and arc welding processes, wherein the joint edges are prepared from one side so as to inclose a U, symetrically disposed about the longitudinal axis of the joint, and its root faces separated. Fig. 62.

21. *Closed Double U Butt Joint:* A butt joint used in the gas and arc welding processes wherein the joint edges are prepared from both sides so as to form two independent U's, approximately symetrically disposed about the longitudinal axis of the joint, and its root faces in contact during welding. Fig. 63.

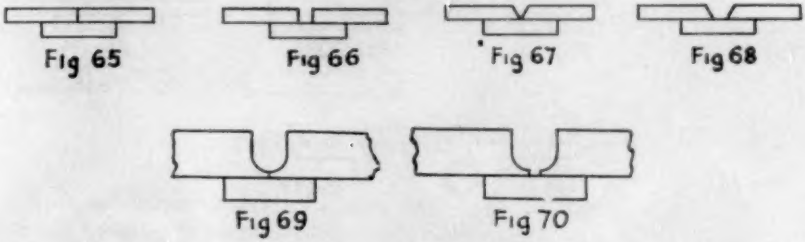
22. *Open Double U Butt Joint:* A butt joint used in the gas and arc welding processes wherein the joint edges are prepared from both sides so as to form two independent U's approximately symetrically disposed about the longitudinal axis of the joint, and its root faces separated. Fig. 64.

23. *Strapped Closed Square Butt Joint:* A closed square butt joint used in the gas and arc welding processes and provided with a strap on the root side of the joint, unless otherwise specified. Fig. 65.

24. *Strapped Open Square Butt Joint:* An open square butt joint used in the gas and arc welding processes and provided with a strap on the root side of the joint, unless otherwise specified. Fig. 66.

25. *Strapped Closed Single V Butt Joint:* A closed single V butt joint used in the gas and arc welding processes and provided with a strap on the root side of the joint, unless otherwise specified. Fig. 67.

26. *Strapped Open Single V Butt Joint:* An open single V butt joint used in the gas and arc welding processes and strapped on the root side of the joint, unless otherwise specified. Fig. 68.



27. *Strapped Closed Single U Butt Joints:* A closed single U butt joint used in the gas and arc welding processes and provided with a strap on the root side of the joint, unless otherwise specified. Fig. 69.

28. *Strapped Open Single U Butt Joint:* An open single U butt joint used in the gas and arc welding processes and provided with a strap on the root side of the joint, unless otherwise specified. Fig. 70.

29. *Single Lap Joint:* A lap joint used in the gas and arc welding processes and consisting of two base metal parts. Fig. 71.

30. *Double Lap Joint:* A lap joint used in the gas and arc welding processes, consisting of three base metal parts, one part being inserted between the two other parts forming two independent lap joints. Fig. 72.

31. *Single Strap Lap Joint:* A lap joint used in the gas and arc welding processes, consisting of three base metal parts, and arranged to form two independent single lap joints. Fig. 73.

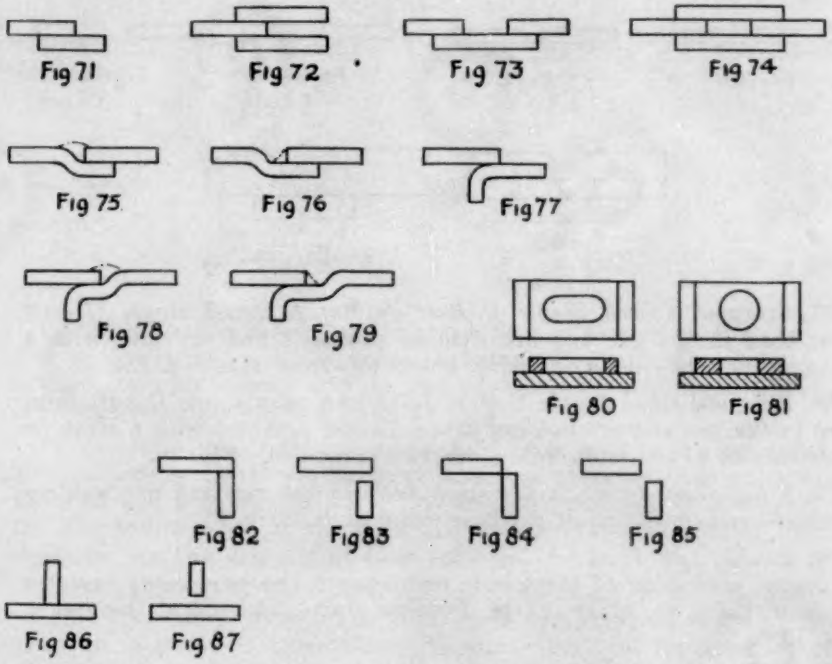
32. *Double Strap Lap Joint:* A lap joint used in the gas and arc welding processes, consisting of four base metal parts, two parts being in the same plane and inserted between the other two parts, forming four independent lap joints. Fig. 74.

33. *Closed Joggled Singled Lap Joint:* A lap single joint used in the gas and arc welding processes, wherein one or the overlapping parts is joggled, the space provided by the joggle being disposed so as to contain a butt weld. Fig. 75.

34. *Open Joggled Single Lap Joint:* A single lap joint used in the gas and arc welding processes wherein one of the overlapping parts is joggled, the space provided by the joggle being disposed so as to contain a fillet weld. Fig. 76.

35. *Flanged Single Lap Joint:* A single lap joint used in the gas and arc welding processes wherein one of the over-lapping parts is flanged. Fig. 77.

36. *Flanged Closed Joggled Single Lap Joint:* A flanged single lap joint used in the gas and arc welding processes wherein the flanged part is joggled, the space provided by the joggle being disposed so as to contain a butt weld. Fig. 78.



37. *Flanged Open Joggle Single Lap Joint:* A flanged single lap joint used in the gas and arc welding processes wherein the flanged part is joggled, the space provided by the joggle being disposed so as to contain a fillet weld. Fig. 79.

38. *Slotted Lap Joint:* A lap joint used in the gas and arc welding processes wherein one of the overlapping parts is provided with a hole or slot. Figs. 80 and 81.

38a. *Linear Slotted Lap Joint:* A slotted lap joint having a slot of rectangular shape with rounded corners. Fig. 80.

39. *Circular Slotted Lap Joint:* A slotted lap joint having a slot of circular shape. Fig. 81.

40. *Closed Lapped Corner Joint:* A corner joint used in the gas and arc welding processes wherein one base metal part overlaps the other and is in contact during welding. Fig. 82.

41. *Open Lapped Corner Joint:* A corner joint used in the gas and arc welding processes wherein one base metal part overlaps the other and is separated. Fig. 83.

42. *Closed Corner Joint:* A corner joint used in the gas and arc welding processes wherein the joint edges are square and enclose a V approximately symmetrically disposed with respect to the longitudinal axis of the joint, the root edges of which are in contact during welding. Fig. 84.

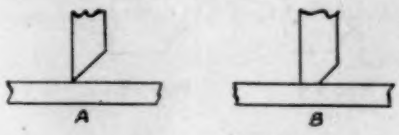


Fig 88

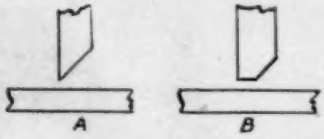


Fig 89.

43. *Open Corner Joint:* A corner joint used in the gas, arc and fusion thermit welding processes wherein the joint edges are square and enclose a V approximately symmetrically disposed with respect to the longitudinal axis of the joint, the root edges of which are separated. Fig. 85.

44. *Closed Square Tee Joint:* A tee joint used in the gas and arc welding processes wherein the joint edge of one part is square and in contact with a surface of the other part during welding, said parts being disposed approximately 90° with respect to each other. Fig. 86.

45. *Open Square Tee Joint:* A tee joint used in the gas, arc and fusion thermit welding processes wherein the joint edge of one part is square and separated from the surface of the other part, said parts being disposed approximately 90° with respect to each other. Fig. 87.

46. *Closed Single Bevel Tee Joint:* A tee joint used in the gas and arc welding processes wherein the joint edge of one part is beveled and its root edge or root face in contact with the surface of the other part during welding. Fig. 88.

47. *Open Single Bevel Tee Joint:* A tee joint used in the gas and arc welding processes wherein the joint edge of one base metal part is beveled and its root edge or root face separated from the surface of the other part. Fig. 89.

48. *Closed Double Bevel Tee Joint:* A tee joint used in the gas and arc welding processes having the joint edge of one base metal part beveled from both sides and its root edge or root face in contact with the surface of the other part during welding. Fig. 90.

49. *Open Double Bevel Tee Joint:* A tee joint used in the gas, arc and fusion thermit welding processes having the joint edge of one base metal

part beveled from both sides and its root edge or root face separated from the surface of the other part. Fig. 91.

50. *Closed Single J Tee Joint:* A tee joint used in the gas and arc welding processes having the joint edge of one base metal part prepared in the form of a J, and its root face in contact with the surface of the other part during welding. Fig. 92.

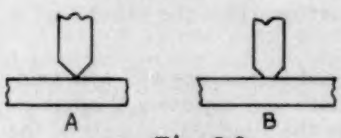


Fig 90

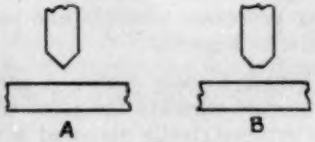


Fig 91

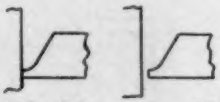


Fig 92 Fig 93

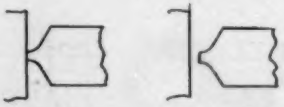


Fig 94 Fig 95

51. *Open Single J Tee Joint:* A tee joint used in the gas and arc welding processes having the joint edge of one base metal part prepared from one side in the form of a J, and its root face separated from the surface of the other part. Fig. 93.

52. *Closed Double J Tee Joint:* A tee joint used in the gas and arc welding processes having the joint edge of one base metal part prepared from both sides in the form of two independent J's, and its root face in contact with the surface of the other part during welding. Fig. 94.

53. *Open Double J Tee Joint:* A tee joint used in the gas and arc welding processes having the joint edge of one base metal part prepared from both sides in the form of two independent J's and its root face separated from the surface of the other part. Fig. 95.

D—FORMS OF WELD

(a) Forge Welding. (b) Pressure Welding. (c) Fusion Welding.

(a) Forms of Welds Used in the Forge Welding Processes

Note: As joints and welds in these processes are more or less synonymous, all parts joined have been classified as "welds" and are defined in Section C (a).

(b) Forms of Welds Used in the Pressure Welding Processes

1. *Jump Butt Weld:* A butt weld made by the resistance butt welding process wherein a rod, tube, strip, etc., of small cross section is welded at right angles to a relatively larger part. Fig. 96.

2. *Tee Butt Weld:* A butt weld made by the resistance butt welding process wherein flat strips, bars, etc., are welded at right angles in the form of a tee. Sometimes a portion of one piece is preheated by the welding current prior to welding. Fig. 97.

3. *Angle Butt Weld:* A butt weld made by the resistance butt welding process wherein the parts are welded at an angle. Fig. 98.

4. *Lap Spot Weld:* A spot weld made by the resistance spot welding process wherein a lap joint is used. Fig. 99.

5. *Bridge Spot Weld:* A spot weld made by the resistance spot welding process wherein the parts are joined by the spot welding of discs or strips across a butt joint. Sometimes termed "Tie Welding." Fig. 100.

6. *Button Spot Weld:* A spot weld made by the resistance spot welding process wherein the parts are joined by the spot welding of discs or buttons between the overlapping joint edges. Fig. 101.

7. *Disc Depression Weld:* A spot weld made by the resistance spot welding process wherein one or both of the overlapping parts to be joined is provided with annular grooves for the reception of discs or buttons to localize the heat. Fig. 102.

Fig 96

Fig 97

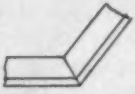


Fig 98

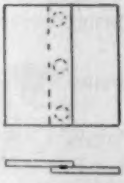


Fig 99

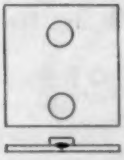


Fig 100

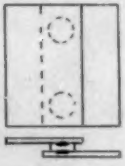


Fig 101

Fig 102

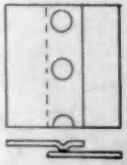


Fig 103

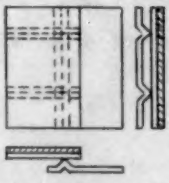


Fig 104

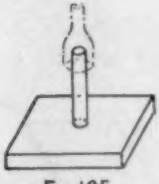


Fig 105

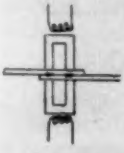


Fig 106

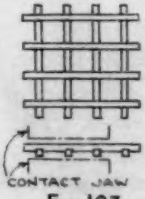


Fig 107

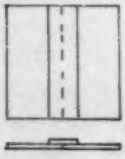


Fig 108

8. *Projection Weld:* A spot weld made by the resistance spot welding process wherein stamped projections to localize the heat are provided in one or both of the overlapping parts to be joined. Fig. 103.

9. *Multiple Projection Weld:* A projection spot weld wherein the contact points cover two or more of the projections in the parts to be joined.

10. *Ridge Projection Weld:* A projection weld made by the resistance spot welding process wherein the parts to be welded are provided with ridges which intersect, thus localizing the heat at points. Fig. 104.

11. *Multiple Electrode Spot Weld:* A spot weld made by the resistance spot welding process wherein several contact points are simultaneously operated.

12. *Tee Spot Weld:* A spot weld made by the resistance spot welding process wherein the parts to be welded form a tee, one of the parts being held in a hollow electrode. Fig. 105.

13. *Duplex Spot Weld:* A spot weld made by the resistance spot welding process wherein two spots are welded simultaneously by the simultaneous use of two transformers on opposite sides of the sheets to be welded, the current passing through two secondaries. Fig. 106.

14. *Mash Weld:* A spot weld made by the resistance spot welding process wherein overlapping rods, wires, strips, etc., are welded between relatively large contact point. Fig 107.

15. *Butt Seam Weld:* A seam weld made by the resistance seam welding process wherein a butt joint is used and the edges progressively welded.

16. *Lap Seam Weld:* A seam weld made by the resistance seam welding process wherein a lap joint is used.

17. *Bridge Seam Weld:* A seam weld made by the resistance seam welding process wherein a strap is welded across a butt joint. Fig. 108.

(c) Forms of Welds Used in the Fusion Welding Processes

1. *Bead:* A single linear deposit of weld metal made by the gas and arc welding processes. Fig. 109.

Fig. 109

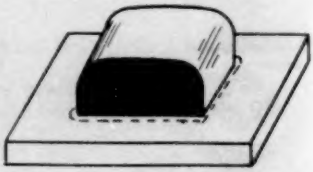


Fig. 110

2. *Pad:* A local superimposed deposit of weld metal made by the gas, arc and thermit welding processes. Fig. 110.

3. *Plug Weld:* A butt weld made by the gas and arc welding processes in the confined opening provided in a slotted lap joint, the edges of which are beveled from the root. Fig. 111.

4. *Rivet Weld:* A butt weld made by the gas and arc welding processes in a confined opening provided in two or more base metal parts in contact, said opening being symmetrical with respect to the longitudinal axis and countersunk in at least one of said parts. Fig. 112.

5. *Closed Square Butt Weld:* A butt weld used in the gas and arc welding processes wherein the joint edges are square and in contact during welding. Fig. 113.

6. *Open Square Butt Weld:* A butt weld used in the gas, arc and fusion thermit welding processes wherein the joint edges are square and separated. Fig. 114.

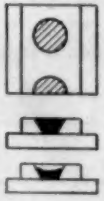


Fig 111

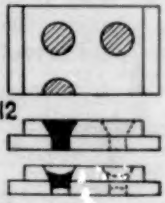


Fig 112

Fig 113

Fig 114

Fig 115

Fig 116

7. *Closed Single V Butt Weld:* A butt weld used in the gas and arc welding processes wherein both joint edges are beveled so as to enclose a "V" symmetrically disposed with respect to the longitudinal axis of the joint, the root edges or root faces of which are in contact during welding. Fig. 115.

8. *Open Single V Butt Weld:* A butt weld used in the gas and arc welding processes wherein both joint edges are beveled so as to enclose a "V" symmetrically disposed with respect to the longitudinal axis of the joint, the root edges or root faces of which are separated. Fig. 116.

9. *Closed Double "V" Butt Weld:* A butt weld used in the gas and arc welding processes, wherein both joint edges are beveled from both sides

about the longitudinal centerline of the joint and its root edges or root faces are in contact during welding. Fig. 117.

10. *Open Double "V" Butt Weld:* A butt weld used in the gas and arc welding processes, wherein both joint edges are beveled from both sides about the longitudinal centerline of the joint and its root edges or faces are separated. Fig. 118.

11. *Closed Single Bevel Butt Weld:* A butt weld used in the gas and arc welding processes, wherein one joint edge is beveled from one side and its root edge or root face is in contact during welding with the opposite square surface. Fig. 119.

12. *Open Single Bevel Butt Weld:* A butt weld used on the gas and arc welding processes wherein one joint edge is beveled and its root edge or root face is separated from the opposite square surface. Fig. 120.

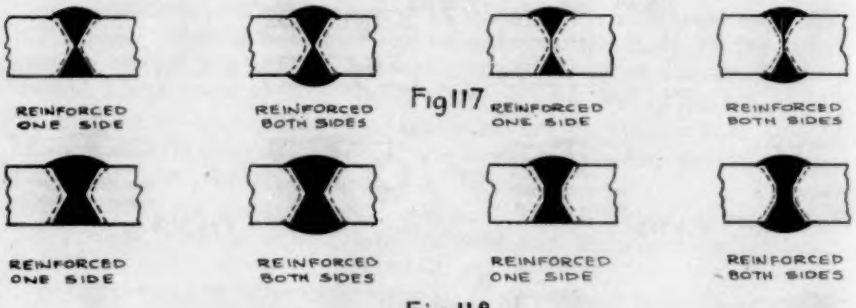


Fig 117

Fig 118

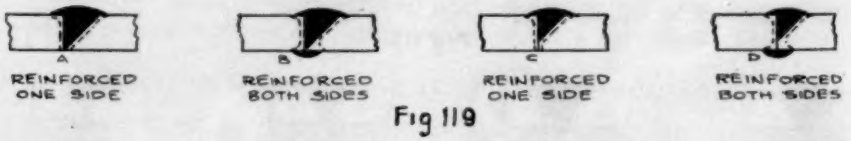


Fig 119

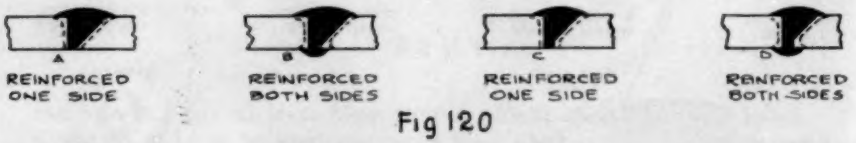


Fig 120

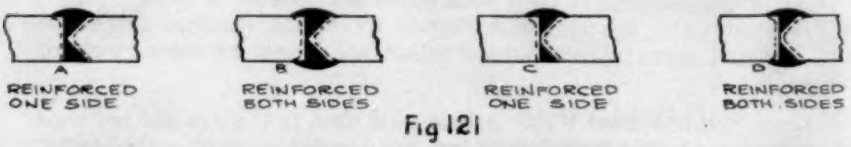


Fig 121

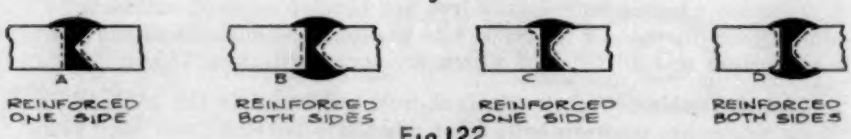


Fig 122

13. *Closed Double Bevel Butt Weld:* A butt weld used in the gas and arc welding processes, wherein one joint edge is beveled from both sides, and its root edge or root face is in contact during welding. Fig. 121.

14. *Open Double Bevel Butt Weld:* A butt weld used in the gas and arc welding processes wherein one joint edge is beveled from both sides and its root edge or root face is separated from the opposite square surface. Fig. 122.

15. *Closed Single "J" Butt Weld:* A butt weld used in the gas and arc welding processes wherein one joint edge is prepared from one side in the form of a "J" and its root face is in contact during welding with the opposite square surface. Fig. 123.

Fig 123

Fig 124

Fig 125 Fig 126

Fig 127

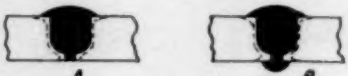


Fig 128

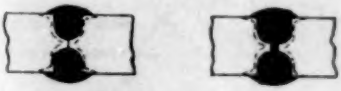


Fig 129 Fig 130

16. *Open Single "J" Butt Weld:* A butt weld having one joint edge prepared from one side in the form of a "J", the root face of which is separated from the opposite surface. Fig. 124.

17. *Closed Double "J" Butt Weld:* A butt weld having one joint edge prepared from both sides in the form of two independent J's, the root face of which is in contact with the opposite surface during welding. Fig. 125.

18. *Open Double "J" Butt Weld:* A butt weld having one joint edge prepared from both sides in the form of two independent J's, the root face of which is separated from the opposite surface. Fig. 126.

19. *Closed Single "U" Butt Weld:* A butt weld having both edges beveled from one side to form a "U" symmetrically disposed about the longitudinal centerline of the joint, the root faces of which are in contact during welding. Fig. 127.

20. *Open Single "U" Butt Weld:* A butt weld having both joint edges beveled from one side in the form of a "U" symmetrically disposed about the longitudinal centerline of the joint, the root faces of which are separated. Fig 128.

21. *Closed Double "U" Butt Weld:* A butt weld having both joint edges prepared from both sides so as to form two independent "U" shaped spaces, symmetrically disposed about the longitudinal centerline of the joint, the root faces of which are in contact during welding. Fig. 129.

22. *Open Double "U" Butt Weld:* A butt weld having both joint edges prepared from both sides so as to form two independent "U" shaped spaces symmetrically disposed about the longitudinal centerline of the joint, the root faces of which are separated. Fig. 130.

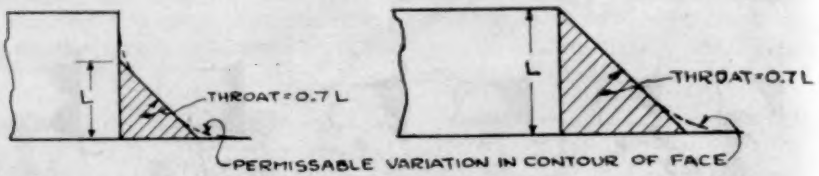


Fig 131

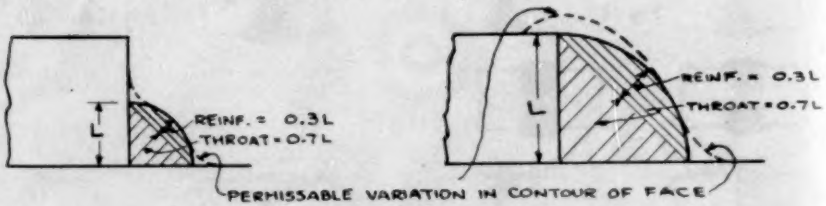


Fig 132

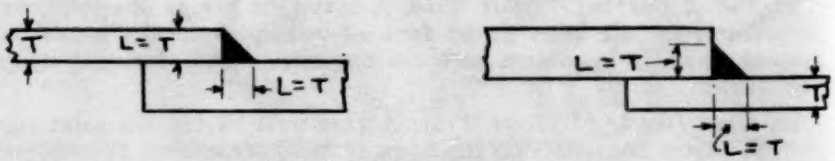


Fig 133

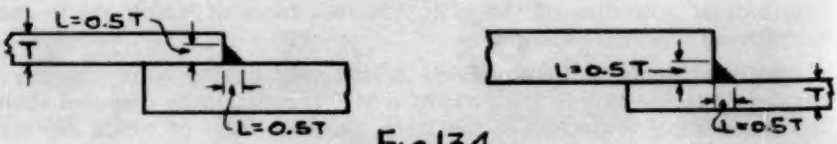


Fig 134

23. *Standard Fillet Weld:* A fillet weld used in the gas and arc welding processes having a cross sectional shape of a right isosceles triangle. Fig. 131.

24. *Standard Reinforced Fillet Weld:* A standard fillet weld having a reinforcement whose depth is not less than 0.3 times the length of the shortest leg of the weld. Fig. 132.

25. *Full Fillet Weld:* A standard fillet weld used in the gas and arc welding processes having legs equal to the thickness of the thinner section joined. Fig. 133.

26. *Light Fillet Weld:* A standard fillet weld used in the gas and arc welding processes having legs equal to one-half the thickness of the thinner section joined. Fig. 134.

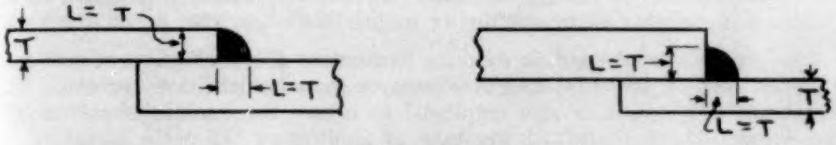


Fig 135

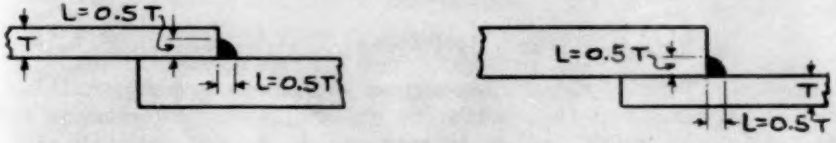


Fig 136

27. *Reinforced Full Fillet Weld:* A standard reinforced fillet weld used in the gas and arc welding processes having legs equal to the thickness of the thinner section joined. Fig. 135.

28. *Reinforced Light Fillet Weld:* A standard reinforced fillet weld used on the gas and arc welding processes having legs equal to one-half the thickness of the thinner section joined. Fig. 136.

E—EQUIPMENT AND SUPPLIES

(a) Miscellaneous. (b) Resistance Welding. (c) Arc Welding. (d) Gas Welding and Cutting. (e) Thermit Welding

(a) Miscellaneous Equipment and Supplies

1. *Backing Strip:* A piece of material (metal, asbestos, carbon, etc.) used to retain molten metal at the root of the weld and/or increase the thermal capacity of the joint so as to prevent excessive warping of the base metal.

2. *Hose:* A flexible conductor for supplying the gases to welding or cutting equipment.

3. *Manifold:* A cross connection for gas cylinders, or for the distribution of the gases used in welding and cutting.

4. *Cylinder:* A container for the gases used in welding and cutting sometimes called a bottle or a tank.

5. *Goggle:* A protective device used in welding and cutting for shielding the operator's eyes, and provided with two independent protective lenses.

6. *Lens:* A specially prepared glass for excluding the harmful infrared and ultra violet rays from the operator's eyes in welding and cutting.

7. *Cover Glass:* A clear glass used to protect the lens in goggles, face shields and helmets from spattering metal.

8. *Flux:* Material used in welding to prevent the formation of oxides, nitrides, etc., in the weld and to eliminate those which have formed. In metal arc welding, it is also employed to retain the various elements of the electrode and to retard the rate of cooling of the weld metal.

9. *Welding Rod:* Filler metal, in wire or rod form, used in the gas and those arc welding processes wherein the electrode does not furnish the filler metal.

(b) Resistance Welding Equipment and Supplies

1. *Contact Point:* An electrical terminal used in a spot welding machine for the application of the electric current and mechanical pressure to the parts to be welded.

2. *Contact Jaw:* An electrical terminal used in a resistance butt welding machine to securely clamp the parts to be welded and conduct the electric current to these parts.

3. *Contact Roller:* An electrical terminal used in a seam welding machine for the application of the electric current and mechanical pressure to the parts to be welded.

4. *Contact Bar:* An electrical terminal used in a seam welding machine for the application of the electrical current and mechanical pressure to the parts to be welded.

5. *Contact Point Insert:* A small disc of metal inserted in a contact point, projecting beyond its surface and having the electrical and physical characteristics required for spot welding.

(c) Arc Welding Equipment and Supplies

1. *Electrode Holder:* A tool used in the arc welding process for mechanically holding the electrode and conducting the electric current to the electrode.

2. *Face Shield:* A protective device used in arc welding for shielding the operator's face, neck and eyes, provided with a window with a protective lens and designed to be held in front of the face by the hand.

3. *Helmet:* A protective device used in arc welding for shielding the operator's face, neck and eyes, provided with a window with a protective lens and designed to be held in place by the operator's head.

4. *Electrode:* Filler metal, in wire or rod form, or a carbon, used as a terminal or terminals in an electric circuit for the purpose of producing an electric arc.

5. *Metal Electrode:* The filler metal used in metal arc welding.

6. *Bare Electrode:* A metal electrode which is not fluxed or covered.

7. *Fluxed Electrode:* A metal electrode provided with a flux.

8. *Coated Electrode:* A fluxed electrode having the flux applied externally by dipping, spraying, painting or otherwise.

9. *Flux Encased Electrode:* A fluxed electrode having the flux between a metal core and sheath.

10. *Covered Electrode:* A metal electrode having an external wrapping or braiding of paper, asbestos or other material. A flux may be included with the covering.

11. *Composite Electrode:* A fluxed electrode having one or more filler materials combined mechanically with the flux or covering.

12. *Carbon Electrode:* The electrode used in carbon arc welding.

13. *Transformer:* A form of stationary induction apparatus by means of which alternating electric energy, applied to one winding commonly called the primary winding, is transformed to alternating electric energy of the same frequency in another winding, commonly called the secondary winding, through the medium of electro-magnetic energy.

14. *Reactor:* A device possessing the property of reactance and used in direct current arc welding circuits to stabilize the arc.

15. *Resistor:* A device possessing the property of electrical resistance. In arc welding circuits it is used to regulate the arc amperes.

16. *Motor Generator Set:* An electrical transforming device consisting of one or more motors mechanically coupled to one or more generators.

17. *Single Operator Motor Generator Set:* A motor generator set designed to supply current to only one welding arc.

18. *Multiple Operator Motor Generator Set:* A motor generator set designed to supply current to two or more welding arcs at the same time.

(d) Gas Welding and Cutting Equipment and Supplies

1. *Welding Torch:* A device used in gas welding processes for mixing and/or regulating the combustion of the gases. Sometimes called a Welding Blowpipe.

2. *Cutting Torch:* A device used in the gas cutting process for regulating and directing the oxygen cutting jet and for mixing and regulating

the combustion of the gases used for pre-heating purposes. Sometimes called a Cutting Blowpipe.

3. *Welding Tip:* That part of a welding torch adjacent to the welding flame and through which the mixed gases issue. Sometimes called a Welding Nozzle.

4. *Cutting Tip:* That part of a cutting torch adjacent to the cutting jet and pre-heating flame and through which the gases issue. Sometimes called a Cutting nozzle.

5. *Mixing Chamber:* That part of a gas welding or cutting torch wherein the gases are mixed.

(e) Thermit Welding Equipment and Supplies

1. *Thermit Mixture:* The combination of the various oxides with aluminum and with alloying metals furnished ready to use in the production of superheated steel or filler metals to be used in pressure and fusion thermit welding processes.

2. *Plain Thermit:* A mixture of finely divided aluminum and iron oxide used usually to produce the superheated molten iron and aluminum oxide used in the pressure thermit welding process.

3. *Forging Thermit:* Plain thermit with the addition of carbon, manganese, nickel and mild steel punchings, the reaction of which produces the superheat and the filler metal in fusion thermit welding of forgings and castings.

4. *Rail Welding Thermit:* Plain thermit with the addition of carbon, manganese, nickel and mild steel punchings, the reaction of which produces the superheat and the filler metal in fusion thermit welding of rails.

5. *Cast Iron Thermit:* Plain thermit with the addition of ferro silicon and mild steel punchings, the reaction of which produces the superheat and the filler metal in fusion thermit welding of cast iron.

6. *Heating Thermit Can:* A can of plain thermit used to increase the temperature of the metal in a ladle or riser.

7. *T. T. Can:* A can of Titanium Iron Thermit used to purify steel in the ladle and at the same time maintain the temperature of the metal.

8. *Slag Basin:* The space provided in the top of a mold for the slag produced by a thermit reaction.

9. *Heating Gate:* The opening in a mold through which the parts to be welded are preheated.

10. *Wax Pattern:* A pattern molded with wax around the joint to be thermit welded and having the form of the completed weld.

11. *Thimble:* A magnesite insert used at the base of a thermit welding crucible and provided with a hole for the tapping pin.

12. *Tapping Pin:* A metal plug used at the base of a thermit welding crucible to tap the molten metal into the mold on completion of the thermit reaction.

SECTION III

ABBREVIATIONS

TERM	ABBREVIATION	ABBREVIATION AS USED	REMARKS AND DESCRIPTION
WELD	W	W-1	USE WHEN IT IS DESIRED TO SPECIFICALLY REFER IN A NOTE TO ONE OR MORE WELDS
WELDED JOINT	WJ	WJ-1	USE WHEN AN ENLARGED DETAIL OF THE JOINT IS MADE THUS:- 3/8, 1/4, 45°, 1/8, WJ-1
BEAD	B	1/4 x 1/2 B	A BEAD 1/4" DEEP AND 1/2" WIDE
REINFORCED WELD	R	1/4 R	1/4" REINFORCED FILLET WELD.
PLUG WELD	P	1/2 P	HOLE 1/2" DIA. AT BOTTOM, STANDARD COUNTERSINK.
CONTINUOUS WELD	① C	1/4	
INTERMITTENT WELD	② INT	1/4 - 2 - 6	F-6", 2"
CHAIN INTERMITTENT FILLET WELD	③ CH	1/4 - 2 - 6	6", 2"
STAGGERED INTERMITTENT FILLET WELD.	S	1/4 - 3 - 12 S	3", 12", 12", 6"
TWO LAYERS	2L	2L	USUALLY LEFT TO SHOP. ONLY USE WHEN MULTIPLE LAYERS ARE CONSIDERED NECESSARY FOR STRESS RELIEF OR TIGHTNESS
THREE LAYERS	3L	3L	
UNDER LAYERS PEENED.	UP	UP	ONLY USE WHEN CONSIDERED NECESSARY FOR STRESS RELIEF OR TIGHTNESS.
ALL LAYERS PEENED	AP	AP	
FINISHED WELD	F	F	ONLY USE WHEN A SMOOTH WELD SURFACE IS ESSENTIAL. LEFT TO THE SHOP TO DETERMINE METHOD OF FINISHING TO BE USED.
WELD FINISHED BY MACHINING.	FM	FM	ONLY USE WHEN A SMOOTH WELD SURFACE IS ESSENTIAL AND METHOD USED IS CONSIDERED IMPORTANT.
WELD FINISHED BY GRINDING	FG	FG	
WELD FINISHED BY PEENING	FP	FP	ONLY USE WHEN CONSIDERED ESSENTIAL FOR APPEARANCE, STRESS RELIEF OR TIGHTNESS.

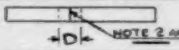
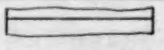
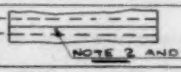
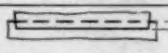
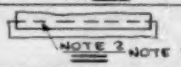
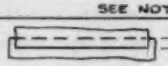
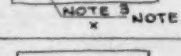
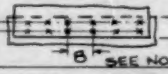
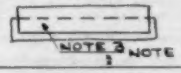
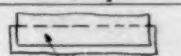
NOTE-

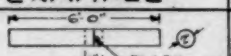
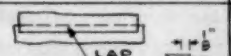
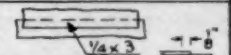
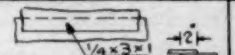
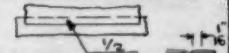
1. NOT USUALLY USED AS ALL WELDS ARE CONTINUOUS UNLESS OTHERWISE SPECIFIED.
2. NOT USUALLY USED AS THE SYMBOL IS OBVIOUS.
3. NOT USUALLY USED AS AN INTERMITTENT WELD, ON BOTH SIDES IS UNDERSTOOD TO BE "CHAIN" UNLESS SPECIFIED "STAGGERED."

FIG. 137—ABBREVIATIONS OF WELDING TERMS AS USED ON DRAWINGS

SECTION IV

SYMBOLS

PROCESS AND SYMBOL		DETAIL OF JOINT	SYMBOL AS USED
BUTT	FLASH OR UPSET		
			
SEAM	BUTT LAP BRIDGE		
SPOT	SINGLE ROW X		
	DOUBLE ROW X X		
	STAGGERED X X X		
	CONTINUOUS XXXXXXXXX		

EXAMPLE	DESCRIPTION
	RESISTANCE FLASH BUTT WELD. TOTAL LENGTH BEFORE WELDING 6'-1", ALLOWING 1" FOR BURNOFF AND PUSHUP.
	RESISTANCE LAP SEAM WELD. PLATE EDGES OVERLAP 1/8"
	SINGLE ROW SPOT WELD. PLATE EDGES OVERLAP 1/8" AND EACH SPOT 1/4" DIA. SPACED 3" C-C.
	DOUBLE ROW SPOT WELD. PLATE EDGES OVERLAP 2". EACH SPOT 1/4" DIA. SPACED 3" C-C ON ROWS 1" APART.
	CONTINUOUS SPOT WELD EACH SPOT 1/2" DIA. PLATE EDGE JOGGLED AND OVERLAPS 1/16"

NOTE-

1. ONLY THE PRINCIPAL RESISTANCE WELDING PROCESSES HAVE BEEN COVERED. SUITABLE NOTATIONS AND DETAIL SKETCHES SHOULD BE USED FOR THOSE NOT SHOWN.
2. GIVE NAME OF SUB-PROCESS USED IF NOT OBVIOUS.
3. GIVE SIZE OF SPOT (A), SPACING (B) AND (C). AS IT IS IMPRACTICABLE WHEN WELDING TO HOLD SIZE AND SPACING OF SPOTS TO EXACT DIMENSIONS SUCH INFORMATION SHOULD BE APPROXIMATE.
4. GIVE APPROXIMATE SIZE OF SPOT.
5. SHOW FREE HAND SKETCH OF JOINT IF NOT OBVIOUS.
6. GIVE FINISHED LENGTH PLUS BURNOFF AND PUSHUP (D)
7. GIVE WIDTH OF OVERLAP (E).

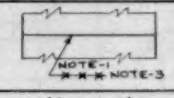
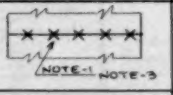
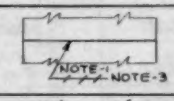
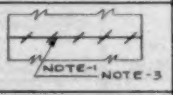
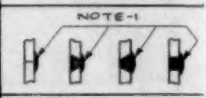
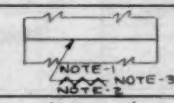
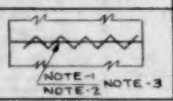
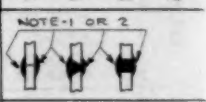
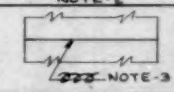
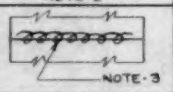
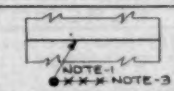
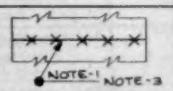
FIG. 138—CONVENTIONAL METHODS OF SHOWING ON DRAWINGS THE NECESSARY INFORMATION REQUIRED TO MAKE WELDS BY THE RESISTANCE WELDING PROCESSES

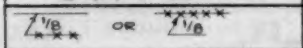
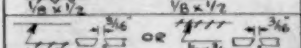
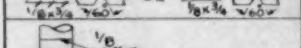
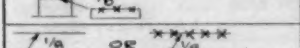
FIG. NO.	SYMBOL	SYMBOLS AS USED IN PLAN AND ELEVATION. METHOD No. 1 PREFERABLE FOR ALL SCALES.	METHOD No. 2 MAY BE USED FOR SCALES 1½ AND ABOVE	METHOD USED FOR SECTIONS
1	FILLET WELD ON NEAR SIDE OF JOINT	NOTE-1 XXX	XXXXXXXX NOTE-1	NOTE-1
2	FILLET WELD ON FAR SIDE OF JOINT	NOTE-1	NOTE-1	NOTE-1
3	FILLET WELD ON BOTH SIDES OF JOINT	NOTE-1	NOTE-1	NOTE-1
4	FILLET WELD ALL AROUND	NOTE-1 NOTE-2	NOTE-1	NOTE-1
5	FILLET WELD TO BE MADE IN THE FIELD	NOTE-1 XXX	XXXXXXX NOTE-1	NOTE-1

EXAMPLE	DESCRIPTION
XXX 5/16 OR 5/16 XXX	5/16" STANDARD CONTINUOUS FILLET WELD ON NEAR SIDE OF JOINT.
3/8-12 OR 3/8-12	3/8" STANDARD CONTINUOUS FILLET WELD 12" LONG ON FAR SIDE OF JOINT.
1/2 R OR 1/2 R	1/2" STANDARD REINFORCED CONTINUOUS FILLET WELD ON FAR SIDE OF JOINT.
XXX XXX 3/8-2-6 OR 3/8-2-6 XXX	3/8" STANDARD INTERMITTENT FILLET WELD ON NEAR SIDE OF JOINT HAVING INCREMENTS 2" LONG, SPACED 6" C-C.
XXX 3/8-2-6 S OR 3/8-2-6 S	3/8" STANDARD INTERMITTENT FILLET WELD ON BOTH SIDES OF JOINT HAVING INCREMENTS 2" LONG SPACED 6" C.-C. ON EACH SIDE AND INCREMENTS STAGGERED WITH RESPECT TO EACH OTHER.
3/8 XXX	3/8" STANDARD FILLET WELD COMPLETELY AROUND THE NEAR SIDE OF JOINT.
XXX 1/4 OR 1/4 XXX	1/4" STANDARD FILLET WELD TO BE MADE IN THE FIELD ON NEAR SIDE OF JOINT.
3/8	3/8" STANDARD CONTINUOUS FILLET WELD.

NOTE:
1. GIVE SIZE AND CONTINUITY OF WELD HERE. SEE EXAMPLES.
2. SHOW SYMBOL FOR LOCATION HERE. SEE EXAMPLE.

FIG. 139—CONVENTIONAL METHODS OF SHOWING ON DRAWINGS THE NECESSARY INFORMATION REQUIRED TO MAKE FILLET WELDS

FIG. No.	SYMBOL	SYMBOLS AS USED IN PLAN AND ELEVATION — METHOD No. 1 PREFERABLE FOR ALL SCALES.	SYMBOLS AS USED IN PLAN AND ELEVATION — METHOD No. 2 MAY BE USED FOR SCALES 1½" AND ABOVE.	METHOD USED FOR SECTIONS
1	REINFORCEMENT ON NEAR SIDE OF JOINT			
2	REINFORCEMENT ON FAR SIDE OF JOINT			
3	REINFORCEMENT ON BOTH SIDES OF JOINT. NOTE- THIS IS THE STANDARD METHOD OF REINFORCEMENT.			
4	WELD FLUSH ON BOTH SIDES OF JOINT. NOTE- ONLY TO BE USED BY SPECIAL PERMISSION.			
5	BUTT WELD ALL AROUND			
6	BUTT WELD TO BE MADE IN THE FIELD.			

EXAMPLE	DESCRIPTION
	BUTT WELD HAVING A REINFORCEMENT ON NEAR SIDE 1/8" DEEP. IF WIDTH IS CONSIDERED ESSENTIAL SPECIFY THUS: 1/8 x 3/4"
	BUTT WELD HAVING A REINFORCEMENT ON NEAR SIDE 1/8" DEEP AND A 1/8" x 1/2" REINFORCEMENT ON FAR SIDE.
	60° SINGLE V BUTT WELD, BEVELED FROM FAR SIDE. A 3/16" OPENING BETWEEN ROOT EDGES AND A 1/8" x 3/4" REINFORCEMENT ON FAR SIDE.
	BUTT WELD COMPLETELY AROUND THE JOINT HAVING A REINFORCEMENT ON NEAR SIDE, 1/8" DEEP.
	BUTT WELD TO BE MADE IN THE FIELD WITH A REINFORCEMENT ON NEAR SIDE, 1/8" DEEP.
	SINGLE V BUTT WELD WITH A 1/8" REINFORCEMENT ON BOTTOM OF V.

NOTE

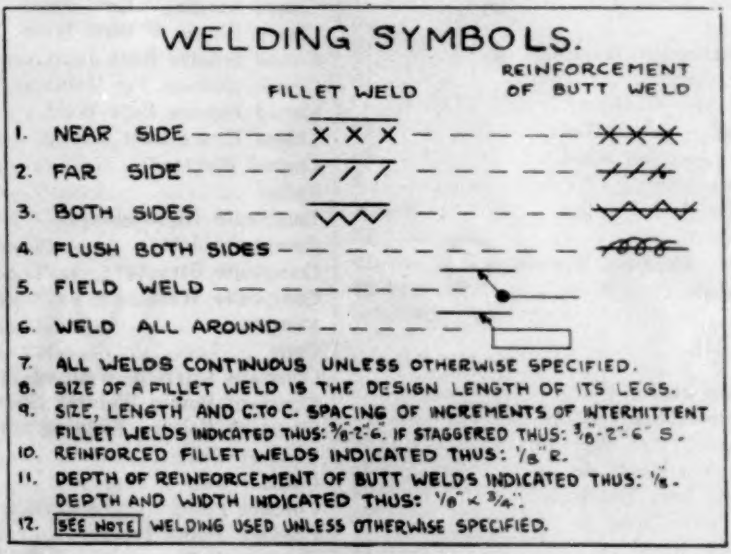
1. GIVE SIZE OF REINFORCEMENT HERE IN TERMS OF DEPTH, OR DEPTH AND WIDTH
2. GIVE SIZE OF REINFORCEMENT ON FAR SIDE HERE, IF DIFFERENT FROM SIZE OF REINFORCEMENT ON NEAR SIDE.
3. MAKE FREE HAND SKETCH OF JOINT HERE IF SHAPE OF JOINT EDGES, SPACING OF ROOT EDGES AND SIDE FROM WHICH BEVELED IS NOT OBVIOUS. THE UPPER SIDE OF THE SKETCH WILL BE UNDERSTOOD AS THE NEAR SIDE.

FIG. 140—CONVENTIONAL METHODS OF SHOWING ON DRAWINGS THE NECESSARY INFORMATION REQUIRED TO MAKE FUSION BUTT WELDS

APPENDIX

WELDING SYMBOLS		
PROCESS		SYMBOL
BUTT	FLASH OR UPSET	———
SEAM	BUTT, LAP OR BRIDGE	═══
SPOT	SINGLE ROW	×
	CONTINUOUS	×××××××
	DOUBLE ROW	× ×
	STAGGERED	× × ×

FIG. 141—SUGGESTED FORM OF STAMP TO BE USED ON DRAWINGS SHOWING RESISTANCE WELDING


WELDING SYMBOLS.
FILLET WELD
REINFORCEMENT OF BUTT WELD
1. NEAR SIDE
2. FAR SIDE
3. BOTH SIDES
4. FLUSH BOTH SIDES
5. FIELD WELD
6. WELD ALL AROUND
7. ALL WELDS CONTINUOUS UNLESS OTHERWISE SPECIFIED.
8. SIZE OF A FILLET WELD IS THE DESIGN LENGTH OF ITS LEGS.
9. SIZE, LENGTH AND C.TO C. SPACING OF INCREMENTS OF INTERMITTENT FILLET WELDS INDICATED THUS: 3/8-2"-6". IF STAGGERED THUS: 3/8-2"-6" S.
10. REINFORCED FILLET WELDS INDICATED THUS: 1/8" R.
11. DEPTH OF REINFORCEMENT OF BUTT WELDS INDICATED THUS: 1/8. DEPTH AND WIDTH INDICATED THUS: 1/8" × 3/4".
12. SEE NOTE WELDING USED UNLESS OTHERWISE SPECIFIED.

NOTE:
SPECIFY ON STAMP THE WELDING PROCESS MOST EXTENSIVELY USED, VIZ: METAL ARC, GAS ETC.

FIG. 142—SUGGESTED FORM OF STAMP TO BE USED ON DRAWINGS SHOWING GAS AND ARC WELDING

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